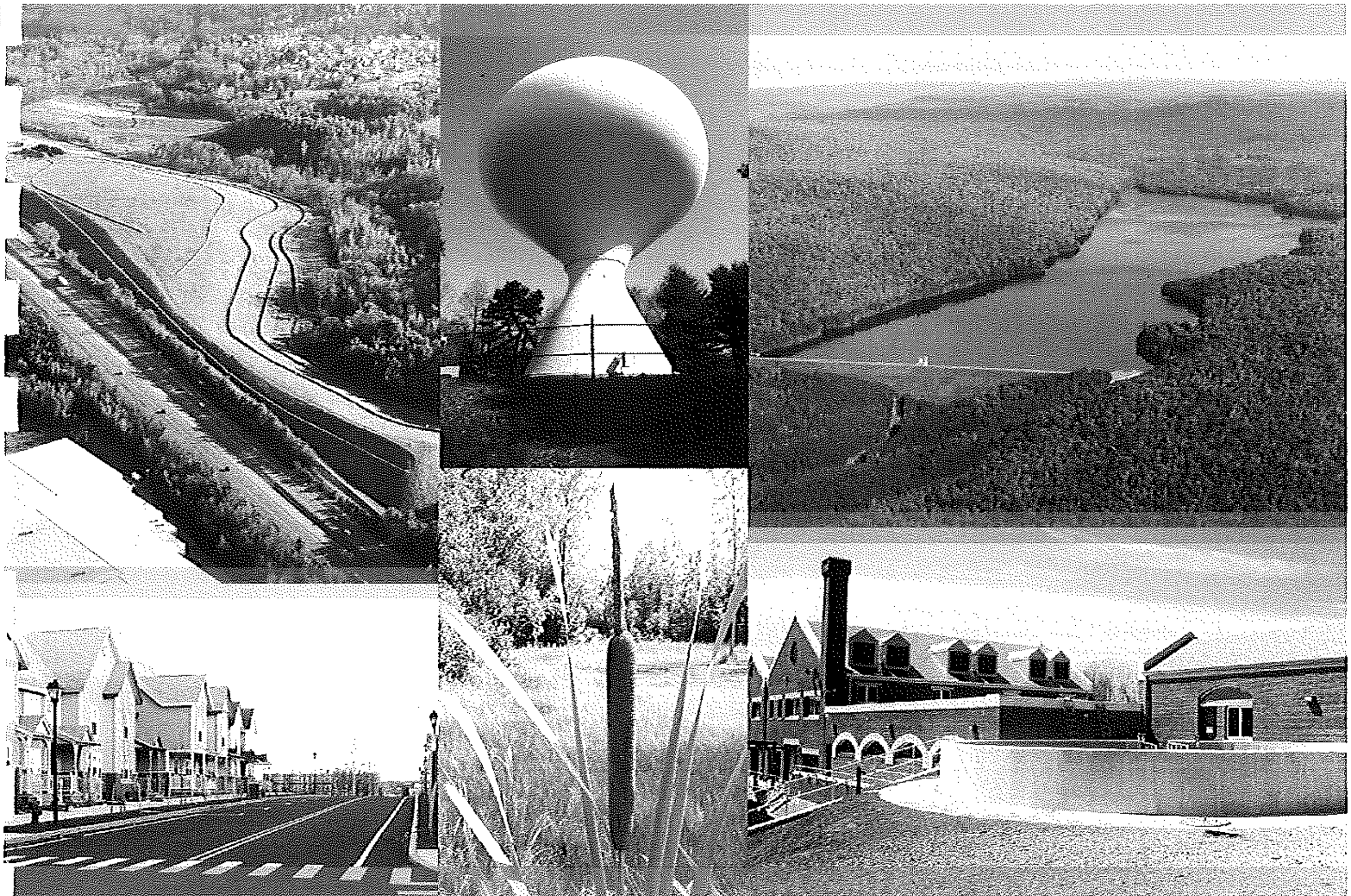

Tighe&Bond

Old Amherst Landfill
Old Belchertown Road
Amherst, Massachusetts

Final Comprehensive Site Assessment (FCSA) Report Volume 1 of 2

Prepared For:

Department of Public Works
Amherst, Massachusetts

January 2009

Tighe&Bond
www.tighebond.com

A-0308-7-04
January 30, 2009

Mr. Daniel Hall, Section Chief
MassDEP Division of Solid Waste Management
436 Dwight Street
Springfield, MA 01103

Re: **Final Comprehensive Site Assessment (FCSA) Report**
Old Amherst Landfill. Amherst MA

Dear Mr. Hall:

On behalf of the Amherst Department of Public Works, Tighe & Bond is submitting to the Massachusetts Department of Environmental Protection (MassDEP) the Final Comprehensive Site Assessment (FCSA) Report for the Old Amherst Landfill site off of Old Belchertown Road in Amherst, Massachusetts.

The FCSA Report was prepared in accordance with the July 6, 2005 MassDEP Initial Site Assessment (ISA) Permit Approval, as modified by MassDEP requirements during the course of the Comprehensive Site Assessment (CSA) study regarding minor changes to the project tasks. The format and content of the FCSA Report follows MassDEP guidance as outlined in the Landfill Technical Guidance Manual (Revised May 1997) and MassDEP *Solid Waste Regulations 310 CMR 19.000*.

If you should have any questions regarding the enclosed FCSA Report, please do not hesitate to contact me at (413) 572-3260.

Very truly yours,

TIGHE & BOND, INC.

Jeffery J. Thelen, P.G.
Senior Hydrogeologist

Enclosures
Copy: Guilford Mooring, P.E., Superintendent (w/encl.)

J:\A\A0308\OLD LF.CSA\0109 MDEP FCSA REPORT TRANS LTR1.DOCX

Enter your transmittal number → X226691
Transmittal Number

Your unique Transmittal Number can be accessed online: http://mass.gov/dep/service/online/trasmfrm.shtml or call MassDEP's InfoLine at 617-338-2255 or 800-462-0444 (from 508, 781, and 978 area codes).

Massachusetts Department of Environmental Protection

Transmittal Form for Permit Application and Payment

1. Please type or print. A separate Transmittal Form must be completed for each permit application.

2. Make your check payable to the Commonwealth of Massachusetts and mail it with a copy of this form to: DEP, P.O. Box 4062, Boston, MA 02211.

3. Three copies of this form will be needed.

Copy 1 - the original must accompany your permit application. **Copy 2** must accompany your fee payment. **Copy 3** should be retained for your records

4. Both fee-paying and exempt applicants must mail a copy of this transmittal form to:

**MassDEP
P.O. Box 4062
Boston, MA
02211**

*** Note:** For BWSC Permits, enter the LSP.

A. Permit Information

BWP SW 23
1. Permit Code: 7 or 8 character code from permit instructions

Comprehensive Site Assessment (CSA)
2. Name of Permit Category

Final Comprehensive Site Assessment (FCSA) Report for the Old Amherst Landfill, Amherst MA
3. Type of Project or Activity

B. Applicant Information – Firm or Individual

Amherst Department of Public Works
1. Name of Firm - Or, if party needing this approval is an individual enter name below:

2. **Last Name** of Individual | 3. **First Name** of Individual | 4. MI

586 South Pleasant Street
5. Street Address

Amherst	MA	01002	(413) 259-3133	
6. City/Town	7. State	8. Zip Code	9. Telephone #	10. Ext. #

Guilford Mooring, P.E.
11. Contact Person

MooringG@amherstma.gov
12. e-mail address (optional)

C. Facility, Site or Individual Requiring Approval

Old Amherst Landfill
1. Name of Facility, Site Or Individual

Old Belchertown Road
2. Street Address

Amherst	MA	01002		
3. City/Town	4. State	5. Zip Code	6. Telephone #	7. Ext. #

SLF# 008-001		
8. DEP Facility Number (if Known)	9. Federal I.D. Number (if Known)	10. BWSC Tracking # (if Known)

D. Application Prepared by (if different from Section B)*

Tighe & Bond, Inc.
1. Name of Firm Or Individual

53 Southampton Road
2. Address

Westfield	MA	01085	(413) 562-1600	3260
3. City/Town	4. State	5. Zip Code	6. Telephone #	7. Ext. #

Jeffery J. Thelen, P.G.
8. Contact Person

9. LSP Number (BWSC Permits only)

E. Permit - Project Coordination

1. Is this project subject to MEPA review? ☐ yes ☒ no
If yes, enter the project's EOEA file number - assigned when an Environmental Notification Form is submitted to the MEPA unit:

EOEA File Number

F. Amount Due

DEP Use Only

Permit No:

Rec'd Date:

Reviewer:

Special Provisions:

1. ☒ **Fee** Exempt (city, town or municipal housing authority)(state agency if fee is $100 or less).
There are no fee exemptions for BWSC permits, regardless of applicant status.
2. ☐ Hardship Request - payment extensions according to 310 CMR 4.04(3)(c).
3. ☐ Alternative Schedule Project (according to 310 CMR 4.05 and 4.10).
4. ☐ Homeowner (according to 310 CMR 4.02).

Check Number	Dollar Amount	Date

Enter your transmittal number → X226691
Transmittal Number

Your unique Transmittal Number can be accessed online: http://mass.gov/dep/service/online/trasmfrm.shtml or call MassDEP's InfoLine at 617-338-2255 or 800-462-0444 (from 508, 781, and 978 area codes).

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2. Last Name of Individual | 3. First Name of Individual | 4. MI

586 South Pleasant Street
5. Street Address

Amherst	MA	01002	(413) 259-3133	
6. City/Town	7. State	8. Zip Code	9. Telephone #	10. Ext. #

Guilford Mooring, P.E.
11. Contact Person

MooringG@amherstma.gov
12. e-mail address (optional)

C. Facility, Site or Individual Requiring Approval

Old Amherst Landfill
1. Name of Facility, Site Or Individual

Old Belchertown Road
2. Street Address

Amherst	MA	01002		
3. City/Town	4. State	5. Zip Code	6. Telephone #	7. Ext. #

SLF# 008-001		
8. DEP Facility Number (if Known)	9. Federal I.D. Number (if Known)	10. BWSC Tracking # (if Known)

D. Application Prepared by (if different from Section B)*

Tighe & Bond, Inc.
1. Name of Firm Or Individual

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2. Address

Westfield	MA	01085	(413) 562-1600	3260
3. City/Town	4. State	5. Zip Code	6. Telephone #	7. Ext. #

Jeffery J. Thelen, P.G.
8. Contact Person

9. LSP Number (BWSC Permits only)

E. Permit - Project Coordination

1. Is this project subject to MEPA review? ☐ yes ☒ no
If yes, enter the project's EOEA file number - assigned when an Environmental Notification Form is submitted to the MEPA unit:

EOEA File Number

F. Amount Due

DEP Use Only

Permit No:

Rec'd Date:

Reviewer:

Special Provisions:

1. ☒ Fee Exempt (city, town or municipal housing authority)(state agency if fee is $100 or less).
There are no fee exemptions for BWSC permits, regardless of applicant status.
2. ☐ Hardship Request - payment extensions according to 310 CMR 4.04(3)(c).
3. ☐ Alternative Schedule Project (according to 310 CMR 4.05 and 4.10).
4. ☐ Homeowner (according to 310 CMR 4.02).

Check Number | Dollar Amount | Date

Massachusetts Department of Environmental Protection
Bureau of Waste Prevention – Solid Waste Management

BWP SW 12 Initial Site Assessment
BWP SW 23 Comprehensive Site Assessment
BWP SW 24 Corrective Action Alternative Analysis
BWP SW 25 Corrective Action Design
Application for Landfill Assessment and Closure

X226691
Transmittal Number

SLF# 008-001
Facility ID# (if known)

A. BWP SW 12 Initial Site Assessment: 310 CMR 19.150(4)

Important: When filling out forms on the computer, use only the tab key to move your cursor - do not use the return key.

Directions: Specify the report/plan and page numbers in which the following information is located.

	Plan/Report #	Page #	DEP Use Only
1. Initial Site Assessment (310 CMR 19.150(4))			
a. Background information			
b. Historical Research			
c. Literature/Data Search			
d. Hydrogeological Description			
e. Site Visit			
f. Mapping			
g. Field Screening			
2. Comprehensive Site Assessment Scope of Work			
3. Funding			
a. Corrective action and/or closure-post closure cost estimate			
b. Funding mechanism and schedule			

B. BWP SW 23 Comprehensive Site Assessment: 310 CMR 19.150(5)

	Plan/Report #	Page #	DEP Use Only
a. ISA Summary	FCSA Report	Section 1	
b. Mapping	FCSA Report	Section 2	
c. Drilling Program	FCSA Report	Section 3	
d. Determination of Hydraulic Conductivity	FCSA Report	Section 3	
e. Sampling and Analysis Plan	FCSA Report	Section 5	
f. Health and Safety Plan	FCSA Report	Appendix C	
g. Project Schedule	Not Applicable		

B. BWP SW 23 Comprehensive Site Assessment: 310 CMR 19.150(5) (cont.)

		Plan/Report #	Page #	DEP Use Only
h.	Baseline Risk Assessment	FCSA Report	Section 6	
i.	Corrective Action Alternative Analysis Scope of Work Outline	Not Applicable		

C. BWP SW 24 Corrective Action Alternative Analysis: 310 CMR 19.150(6)

		Plan/Report #	Page #	DEP Use Only
a.	Corrective Action Objectives			
b.	Alternatives Analysis			
c.	Recommended Alternative			

Important Note: Engineering Plans must be stamped by a Registered Professional Engineer (PE). Property Line Location must be stamped by a Registered Land Surveyor (RLS).

D. BWP SW 25 Corrective Action Design: 310 CMR 19.151(2)(a)

		Plan/Report #	Page #	DEP Use Only
a.	Corrective Action Design and/or closure plans			
b.	Implementation schedule			

E. Post Closure Plans

Note: Part E is only applicable when a closure plan has been submitted and closure is being implemented.

		Plan/Report #	Page #	DEP Use Only
1.	Maintenance Plan {310 CMR 19.142(5)}			
2.	Monitoring Plan {310 CMR 19.142(5)}			
3.	Post-Closure Use Plans {310 CMR 19.143} (if applicable)			
4.	Record Notice of Landfill Operation {310 CMR 19.141}			

Massachusetts Department of Environmental Protection
Bureau of Waste Prevention – Solid Waste Management

BWP SW 12 **Initial Site Assessment**
BWP SW 23 **Comprehensive Site Assessment**
BWP SW 24 **Corrective Action Alternative Analysis**
BWP SW 25 **Corrective Action Design**
Application for Landfill Assessment and Closure

X226691
Transmittal Number

SLF# 008-001
Facility ID# (if known)

F. Certification & Engineer's Supervision: 310 CMR 19.011

Engineer's Supervision:

All papers pertaining to design, operation, or engineering of this site or facility shall be completed under the supervision of a Massachusetts registered professional engineer knowledgeable in solid waste facility design, construction and operation, and shall bear the seal, signature and discipline of said engineer. The soils, geology, air monitoring and groundwater sections of the application or monitoring report shall be completed by competent professionals experienced in the fields of soil science and soil engineering, geology, air monitoring and groundwater, respectively, under the supervision of a Massachusetts registered professional engineer. All mapping and surveying shall be completed by a registered surveyor.

Peter M Valinski, P.E.
Print Name

Authorized Signature

Vice President
Position/Title

Tighe & Bond, Inc.
Company

38143
P.E. #

1/29/09
Date

COMMONWEALTH OF MASSACHUSETTS
PETER M. VALINSKI
CHEMICAL
No. 38143
REGISTERED
PROFESSIONAL ENGINEER

Certification:

Any person, required by these regulations or any order issued by the Department, to submit papers shall identify themselves by name, profession, and relationship to the applicant and legal interest in the facility, and make the following certification: "I certify under penalty of law that I have personally examined and am familiar with the information submitted in this document and all attachments and that, based on my inquiry of those individuals immediately responsible for obtaining the information, I believe that the information is true, accurate and complete. I am aware that there are significant penalties both civil and criminal for submitting false information including possible fines and imprisonment."

Jeffery J. Thelen, P.G.
Print Name

Jeffery J. Thelen
Authorized Signature

Senior Hydrogeologist
Position/Title

1/29/09
Date

J:\A\A0308\Old LF CSA\0109 FCSA Report5.docx

Section 1 Introduction

The Final Comprehensive Site Assessment (FCSA) Report of the Old Amherst Landfill site was conducted in accordance with Massachusetts Department of Environmental Protection (MassDEP) correspondence and approvals as follows:

- *July 6, 2005 Initial Site Assessment (ISA) Permit Approval*
- *October 27, 2005 Interim CSA SOW Approval - Modification*
- *October 23, 2007 Interim CSA Permit Approval*
- *February 14, 2008 FCSA Deadline Extension*
- *October 10, 2008 FCSA Additional Sediment and Surface Water (MassDEP email)*
- *October 28, 2008 FCSA Deadline Extension (MassDEP email approval)*
- *December 29, 2008 Risk Assessment - Sediments*

These documents are provided in Appendix A.

1.1 General

The Town of Amherst retained Tighe & Bond to evaluate and characterize existing conditions at the closed Old Amherst Landfill site located on Old Belchertown Road (Route 9) in Amherst Massachusetts. The landfill site is currently maintained as open space and is unused by the Town with the exception of snow storage during winter months. The main access road into the site is gated and fenced although the majority of the site is not fenced.

The landfill consists of three (3) general waste disposal areas, a municipal solid waste (MSW) disposal area, a concrete and masonry demolition disposal area, and a wood and stump dump area. The main MSW disposal area occupies the northern half of the site. The concrete and masonry demolition disposal area occupies the northeastern portion of the site quarter of the site. The wood and stump dump area occupies the southern portion of the site. All waste disposal areas were closed and capped in 1986 using a variable depth clay soil barrier system (landfill cap or final cover system). Since that time, MassDEP landfill cover system requirements have become more stringent as part of an effort to protect the environment and mitigate groundwater contamination typically associated with unlined waste disposal areas.

The 1986 clay soil barrier system was a variable depth final cover system consisting of:

- vegetative cover; turf grasses and wildflower mixture
- top soil, minimum 2-inch depth
- gravel drainage layer, minimum 4-inch depth

- clay layer; minimum 6-inch depth
- gravel grading layer; variable depth
- existing cover material; variable depth

Locus and GIS-based site plans are provided in Appendix B that shows the general relation of the site to the surrounding area.

1.2 CSA Scope of Study

The CSA is the second phase of the three (3) landfill assessment phases outlined in the MassDEP Landfill Technical Guidance Manual. MassDEP requires assessment of landfill sites to identify and address any potential site impacts to human health, public safety or the environment. The assessments are required under *Massachusetts Solid Waste Regulations 310 CMR 19.150 Landfill Assessment Requirements.*

The CSA study consists of an investigation intended to characterize the impact of the landfill on public health, safety and the surrounding environment. The investigation typically includes detailed site mapping, installation of groundwater monitoring wells, assessment of groundwater and surface water quality, installation of gas monitoring probes or wells, assessment of off-site landfill gas migration, characterization of site hydrogeology, determination of potential contaminant migration pathways, identification of principle "contaminants of concern (COCs)", evaluation of the potential risk to human health, public safety and the environment, study conclusions and recommendations, and a recommended Scope-of-Work for the third phase of assessment entitled the Corrective Action Alternatives Analysis (CAAA), if warranted.

The MassDEP outlined the overall CSA scope of work in the *July 6, 2005 Initial Site Assessment (ISA) Permit Approval*. The CSA study was conducted in two phases, as an Interim CSA study and Final CSA study (FCSA). The first phase involved the completion of an Interim CSA Report based primarily on the collection of environmental monitoring data from existing groundwater monitoring and test wells, surface water and sediment stations, perimeter soil gas assessment and evaluation of landfill cover. The second phase of the CSA study focuses on groundwater quality and sediment assessment with the installation of groundwater monitoring wells upgradient, at the landfill and downgradient of the site and additional sampling of wetland sediments at impacted groundwater discharge areas.

1.3 Interim CSA Report Summary

The Interim CSA study of the Old Amherst Landfill focused on the collection and analysis of groundwater samples from existing monitoring and test wells, evaluation of groundwater contour data, collection of surface water samples and sediment samples from potential downgradient surface water receptors (some visually affected by iron staining), evaluation of subsurface migration at the perimeter of the landfill site, ambient air monitoring at the site, and characterization of landfill cover. One of the primary goals of the Interim CSA study was to provide recommendations for additional well installation and assessment to complete the CSA study. Interim CSA study findings are summarized in the following categories:

- Soil Gas Assessment & Air Monitoring

- Landfill Cover Evaluation
- Hydrogeologic Characterization
- Environmental Monitoring & Contaminant Characterization

1.3.1 Soil Gas Assessment & Air Monitoring

Seven gas monitoring wells (PGW-1 through PGW-7) were installed on the perimeter of the landfill site to check the presence of subsurface landfill gas emissions. Locations are shown on study plans provided in Appendix B.

- The gas monitoring wells were installed to a depth of 50 feet or a minimum of 5-feet into the groundwater table, with the exception of PGW-6 installed to a depth of 88 feet for groundwater sampling purposes. The wells were screened and sand packed through the vadose zone to a depth of 5 feet below the water table. Overall, soils encountered were fine to medium sands overlying very fine sand and silt at depth.

- Subsurface landfill gas monitoring of the seven perimeter gas monitoring wells and existing soil gas points indicated that landfill gases were not detected in the subsurface off of Town owned landfill property.

A 100-foot grid was established across the site to facilitate ambient air monitoring and the evaluation of existing soil cover. A total of 209 grid stations were established across the 40-acre site.

- An ambient air survey conducted across the surface of the landfill at a height of 5 feet did not detect any landfill gas impacts to the "breathing zone" of a site worker or site user.

1.3.2 Landfill Cover Evaluation

A "test hole" evaluation was conducted across the landfill at a spacing of one shallow boring per acre to evaluate the depth of cover, characterize the barrier layer soils, check shallow soil gas in each boring above the barrier layer soils, check the hydraulic conductivity of the barrier layer at select locations, and collect and analyze topsoil samples for chemical analyses.

- The landfill cover characterization indicated that the soil cover across the landfill is fairly consistent, varying from 7 to 15 inches of topsoil overlying 5 to 12 inches of barrier layer soils.

- Soil gas monitoring of the test holes prior to penetrating the barrier layer did not detect any landfill gases.

- Hydraulic conductivity testing of the barrier layer material indicated that the hydraulic conductivity from 3.4×10^{-4} cm/s to 2.7×10^{-6} cm/s for the soils evaluated. It was noted that sample integrity may have been compromised by heavy rainfall during sampling that caused seepage of water into the test holes, possibly intermixing soil of the barrier layer with overlying soils.

- Analysis of cover soils for metals and volatile organic compounds (VOCs) indicated that all metals concentrations were less than MassDEP MCP RC S-1 guidance levels for playground, recreational and drinking water areas. No target VOC analytes were detected. Three non-target VOCs were detected at trace levels in various samples; these may be due to the sample preservation method.

1.3.3 Hydrogeologic Characterization

New gas monitoring wells and existing test or monitoring wells that required elevation control were surveyed by the Town Engineering Department. Surveyed well elevations were used to calculate groundwater elevations.

- Groundwater elevations measured in November 2005 were used to construct the site Groundwater Contour Plan provided in Appendix B. The groundwater elevation data was supplemented with spot elevations of surface waters and wetlands to better define groundwater flow paths downgradient of the site.

- The November 2005 groundwater contours indicate an overall westerly flow from the landfill site, towards Hop Brook and associated wetlands.

- Site groundwater elevation data indicates a very steep hydraulic gradient along the western edge of Pomeroy Pond, flattening to the west across and downgradient of the landfill site.

- Groundwater flow from the landfill was not projected to impact the area to the south of well #1-03, approximately 1,000 feet southwest of the site waste disposal limits.

1.3.4 Environmental Monitoring & Contaminant Characterization

The environmental monitoring program for the Interim CSA study was conducted in November 2005. The program included collection and analysis of 13 groundwater samples, and 9 surface water samples and 9 sediment samples. Analytical parameters included all general water chemistry, metals and VOC analyses required under *Massachusetts Solid Waste Regulation 310 CMR 19.132(1)h* with the addition of pesticide analyses for the groundwater samples. Total metals were analyzed at all sampling stations. Potential "Contaminants of Concern or COCs" were identified by comparison to applicable standards as summarized below:

- Groundwater COCs included the metals barium (Ba), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), manganese (Mn), mercury (Hg) and zinc (Zn). Metals analysis was by "total" metals (not dissolved) in the groundwater. No volatile organic compounds (VOCs) were identified as COCs in groundwater.

- Other potential landfill groundwater quality impacts include slightly to moderately elevated levels of alkalinity, chemical oxygen demand (COD), chloride, sulfate and TDS, and trace concentrations of VOCs at levels less than 10 ug/L (<10 ppb).

- Surface water COCs included a dissolved oxygen content of less than 5 mg/L, and the metal lead (Pb). No VOCs were identified as COCs in the surface water.

- Other potential landfill surface water quality impacts are moderately elevated to elevated levels of barium (Ba), iron (Fe) and manganese (Mn), and trace concentrations of VOCs at levels less than 10 ug/L.

- Sediment COCs include the metals arsenic (As), copper (Cu), iron (Fe), lead (Pb), manganese (Mn), mercury (Hg) and zinc (Zn). No VOCs were identified as COCs in the sediment samples.

- Other potential landfill sediment quality impacts are moderately elevated to elevated levels of alkalinity, COD and chloride, and moderately elevated levels of the metal barium (Ba).

1.4 FCSA Scope of Work

In the Interim CSA Report, Tighe & Bond proposed a "Phase 2" CSA Scope of Work that focused on characterization of hydrogeology downgradient of the site and water quality impacts, and completion of landfill assessment activities as required by MassDEP. The proposed work was modified by the MassDEP and included the following items:

1.4.1 Updated Private Well Survey

MassDEP required that the Town update the existing private well survey of residential water supply wells within a ½-mile radius from the landfill site, including extending the survey boundaries to the Fort River west and northwest of the site and to Hop Brook west and southwest of the site.

1.4.2 FCSA Groundwater Monitoring Wells

Eight additional groundwater monitoring wells were recommended in the Interim CSA Report for the second phase of the CSA study. New monitoring wells were proposed at five locations: one upgradient, 3 downgradient and the fifth location at existing Lawrence Swamp Aquifer monitoring well #1-03. Monitoring well locations are described as follows:

- **Upgradient Well #1-08:** Shallow upgradient well screened in the upper 10 feet of saturated soils; the well is located along Old Belchertown Road to the east of the MSW disposal area and the C&D disposal area as an upgradient well to characterize background groundwater quality conditions.

- **Downgradient Well Cluster #6-08 and #7-08:** Shallow and confined aquifer wells installed adjacent to Gull Pond near the SW-1 surface water station.

- **Downgradient Well Cluster #10-08 and #11-08:** Shallow and confined aquifer wells installed east of the SW-6 surface water station along Old Farm Road, roughly 200 feet south of the intersection with Pine Grove Road.

- **Downgradient Well Cluster #8-08 and #09-08:** Shallow and confined aquifer wells installed at the alternate location identified in the Interim CSA Report as the intersection of Hop Brook Drive and Old Farm Road based on drilling access restrictions at the initial proposed location.

- **Downgradient Well #12-08:** Confined aquifer well installed adjacent to shallow monitoring well #1-03 located along the sewer pump station access road that intersects Woodlot Road. Well #1-03 is used by the Town to monitor for changes in water quality that may affect the Lawrence Swamp Aquifer. (A confined aquifer well at this location strengthens the monitoring well network designed to protect the aquifer from contamination due to either the Old Amherst Landfill or residential development in Amherst Woods.)

MassDEP added the following monitoring wells as part of *Interim CSA Report Approval dated October 23, 2007.*

- **Landfill Well #2-08:** Shallow well installed and screened in the upper portion of the shallow aquifer along the north-northwest perimeter of the site.

- **Landfill Well #3-08:** Shallow well installed and screened in the upper portion of the shallow aquifer along the western perimeter of the site, south of the former location of Amherst Auto Parts (former on-site junkyard).

- **Lawrence Swamp Well #4-08:** Bedrock well installed along Station Road at the intersection of the railroad tracks adjacent to existing Lawrence Swamp monitoring wells #4-83 and #2-85.

- **Landfill Well #5-08:** Deep bedrock well installed adjacent to existing well #PGW-6 on the western perimeter of the landfill.

Most of the groundwater monitoring wells were proposed as part of "well clusters" generally consisting of a shallow well screened in the upper surficial aquifer and a deeper well installed in the underlying confined aquifer, where it exists downgradient of the landfill in the Lawrence Swamp basin. Surficial wells are used to characterize potential landfill impact while deeper "confined aquifer" wells will enable monitoring of the confined aquifer at these locations for potential landfill water quality impacts to the underlying confined aquifer.

1.4.3 FCSA Gas Monitoring Wells

MassDEP added the two gas monitoring wells to the FCSA scope of work as part of *October 23, 2007 Interim CSA Report Approval:*

- **Perimeter Gas Monitoring Well PGW-8:** Shallow gas monitoring well installed and screened in the upper 15 feet of soils along the north-northwest perimeter of the site and adjacent to well #2-08.

- **Perimeter Gas Monitoring Well PGW-9:** Shallow gas monitoring well installed and screened in the upper 15 feet of soils along the western perimeter of the site and adjacent to well #3-08.

1.4.4 FCSA Environmental Monitoring

MassDEP required environmental monitoring as outlined below:

1.4.4.1 Groundwater

One round of analysis of groundwater for the parameters outlined under *Massachusetts Solid Waste Regulations 310 CMR 19,132(1)h* including landfill contaminant indicator parameters, metals and volatile organic compounds (VOCs).

Stations to be sampled include the fourteen new FCSA monitoring wells and fourteen existing monitoring wells.

1.4.4.2 Surface Water

One round of analysis of surface water for the parameters outlined under *Massachusetts Solid Waste Regulations 310 CMR 19,132(1)h* including landfill contaminant indicator parameters, metals and volatile organic compounds (VOCs)

Stations to be sampled are the eight previous surface water stations (SW-1 thru SW-8) and nine additional surface water stations (SW-9 thru SW-17). (Station SW-17 at the brickyard well field was substituted for a groundwater monitoring well at this location.)

1.4.4.3 Sediment

One round of sampling and analysis of sediment for the parameters outlined under *Massachusetts Solid Waste Regulations 310 CMR 19,132(1)h* including RCRA 8 metals and volatile organic compounds (VOCs)

Stations are: SED-1, SED-4, SED-5, SED-6, SED-7, SED-8, SED-14, SED-15 and SED-16.

1.4.4.4 Soil Gas

One round of soil gas monitoring of existing and new gas monitoring wells and existing soil gas points for percent methane, percent oxygen and hydrogen sulfide gas in parts per million (ppm). Reporting of soil gas monitoring data shall be in conformance with *MassDEP Solid Waste Regulations 310 CMR 19.132(4)* including requirements for 2-hour and 24-hour notifications.

1.4.5 Additional Sediment and Surface Water Sampling

MassDEP required in email correspondence dated October 10, 2008 additional sampling and analysis based on the results of FCSA surface water and sediment analyses.

1.4.5.1 Sediment

Additional sediment sampling and analysis as follows:

Station SED-1: Four samples for arsenic (As) with one sample in the approximate SED-1 location, then one west, one east and one south.

KC Trail Area (Stations SED-6 and SED 6 A thru L, SED-14 and SED-16): Ten samples for arsenic (As) and cadmium (Cd) located along edges of the visibly-impacted wetland area and within the wetland to delineate metal concentrations.

Station SED-15: Three samples for mercury (Hg) analysis. One sample in the approximate SED-15 location and two nearby samples collected at the edges of the wetland area.

1.4.5.2 Surface Water

Additional surface water sampling and analysis as follows:

Station SW-15: Three additional surface water samples at the SW-15 wetland to be obtained and analyzed for cyanide and dissolved lead (Pb).

1.4.6 LAC Items: Pages C-26 through C-29

The MassDEP Landfill Technical Guidance Manual (LAC Manual) outlines under pages C-26 through C-29 the specific CSA Report submittal requirements. In addition to updating the information submitted for the Interim CSA Report and the ISA Report, the following will be provided:

- Interpretation of geologic stratigraphy including two geologic cross sections

- Calculation of the landfill mass water balance
- Determination of hydraulic conductivity for new CSA monitoring wells
- Identification of contaminant migration pathways
- Conduct a baseline qualitative risk assessment

1.5 FCSA Health & Safety Plan

A site specific Health & Safety Plan (HASP) was prepared for CSA study assessment activities such as drilling and sampling. The HASP provides a basic description of existing site conditions and provides background information to advise site workers relative to general site hazards. The HASP also describes specific personnel protection measures, communication procedures, personnel and equipment decontamination procedures, emergency medical procedures and notification information, and a summary of identified site hazards.

Given the site history, the site hazards identified in the HASP were limited to heavy equipment working on the site, general biological hazards such as ticks, poison ivy, and bees and typical landfill-type impacts such as exposure to landfill gas emissions, and various media impacted with chemicals, such as metals and/or volatile organic compounds (VOCs) in groundwater, surface water or sediment. A copy of the HASP is provided in Appendix C of this report submittal.

Section 2
FCSA Mapping & Field Activities

2.1 Site Mapping

Site plans prepared for the FCSA were developed from Town of Amherst aerial and GIS mapping provided on October 19, 2003 to Tighe & Bond. The GIS mapping is equivalent to mapping used for the Interim CSA Report and includes two-foot contour intervals, property lines, wetlands and surface water resources.

The following plans have been prepared for the FCSA Report and are provided in Appendix B:

- *CSA Site Base Plan (Sheet 1 of 3)* – This plan has been prepared at a scale of 1"=200' and includes groundwater and soil gas monitoring well locations, water supply test well locations, surface water and sediment sample stations, property lines, structures, wetland and surface water resource boundaries.

- *August 2008 Groundwater Contour Plan (Sheet 2 of 3)* - This plan has been prepared at a scale of 1"=200' and is based on groundwater elevation data collected on August 28, 2008 and estimated surface water elevations. The plan includes groundwater elevation contours for both the surficial aquifer and groundwater flow directions downgradient of the landfill site.

- *Geologic Cross Sections (Sheet 3 of 3)* – Four geologic cross sections were prepared to graphically evaluate the underlying stratigraphy, identify principal aquifer and confining units, and characterize contaminant migration pathways in the subsurface. The cross section lines are shown on the FCSA Site Plan and August 2008 Groundwater Contour Plan.

2.2 Field Survey

New groundwater monitoring wells and perimeter gas monitoring wells were surveyed by Town Engineering Department staff in October 2008 and January 2009. Sediment stations at the KC Trail wetland area (SW-6 wetland) and Gull Pond inlet (SW-1 wetland) were surveyed by the Town in October 2008.

2.3 Updated Private Well Survey

An updated private well survey of existing residential water supply wells was prepared and submitted to the MassDEP in February 2008. The MassDEP had required that the Town update an existing landfill private well survey for a ½-mile radius from the landfill site including extending the survey boundaries to the Fort River west and northwest of the site and to Hop Brook west and southwest of the site. The February 2008 Update Private Well Survey report is included as Appendix D.

The updated survey identifies a total of 24 private residential water supply wells within the study boundaries. However, no private wells are located downgradient of the Old Amherst Landfill site.

2.4 Site Mass Water Balance

The mass water balance evaluation for the Old Amherst Landfill was performed using the *US EPA Hydrologic Evaluation of Landfill Performance (HELP) Model*, Version 3.0, 1993 by P.R. Schroeder, N. M. Aziz, C. M. Lloyd, and P. A. Zappi, EPA/600/9-94xxx, U.S. Environmental Protection Agency Risk Reduction Engineering Laboratory, Cincinnati, OH. The HELP Model is a quasi-two-dimensional hydrologic model used to simulate and provide estimates of surface water runoff, evapotranspiration, lateral drainage, infiltration and leachate generation at landfill sites based on simulated climatological, soil and landfill design data. The HELP Model accesses a database of climatic data for a number of cities and towns across the United States. For this landfill mass water balance evaluation, climatic data for Worcester, Massachusetts, corrected for latitude (42° 21'), was used to model site conditions.

The HELP Model was used to evaluate leachate generation rates for current (year 2008) conditions for the existing closed unlined landfill area. Other closure options were not evaluated since the facility was closed in accordance with the regulations in effect at the time of closure, a nominal 2-foot thick soil barrier final cover system (landfill cap).

2.4.1 HELP3 Model Assumptions

Site and soil criteria for the HELP Model evaluation were estimated based on field observations that are detailed in the January 2006 Interim CSA Report. The soil cover was evaluated using technical specifications and soils criteria contained in the model. The HELP Model mass water balance output is summarized in Table 2.1 at the end of this Section. The mass water balance model output is based on simulated precipitation and weather data over a five-year interval for the geographical area selected for evaluation. Assumptions and parameters used to evaluate the landfill mass water balance are as follows:

- The waste disposal area at the Old Amherst Landfill was estimated at 33.64 acres based on the approximate limit of cap shown on the Site Orthophoto Plan included in the January 2006 Interim CSA Report.

- The average slope of the ground surface was estimated as 2 percent across the site to the perimeter with 100% allowable drainage, i.e., no internal ponding of runoff. Slope length was nominally estimated at 500 feet.

- Vegetation was estimated to be equivalent to an overall average stand of "good" quality grass, taking into account that the majority of the landfill is covered with a mixture of grass vegetation.

- The average depth of soil cover was estimated at 2.0 feet or 24-inches; the soil cover was modeled as 12-inches of loamy fine sand soil overlying 8 inches of a silty clay barrier soil (saturated hydraulic conductivity of 1.1×10^{-4} cm/s) and 4-inches of fine sand. The evaporative depth was estimated at 20 inches.

  Soil cover depth and characteristics were based on the results of the final cover system (landfill cap) test hole evaluation described in *Section 2.4.1 Landfill Cover Characterization* and *Section 2.4.3 Barrier Layer Characterization* of the *January 2006 Interim CSA Report*.

- The depth of waste was estimated to average 35 feet.

2.4.2 HELP3 Model Results

A summary of the HELP Model results for existing site conditions is presented in Table 2.1 at the end of this Section.

The HELP evaluation indicates that the current leachate generation rate at the site is about 940 gallons per day per acre (gpd/Acre). The quantity of leachate generated at the Old Amherst Landfill through the infiltration of precipitation and discharged to the subsurface is estimated at about 11,500,000 gallons/year for the 33 acre landfill area.

HELP Model output can vary considerably from actual field conditions depending on how well the general assumptions used to model the site reflect actual characteristics. Field variations in soil type; compaction, vegetation and drainage slope can considerably change infiltration and leachate generation rates. Also, leachate generated on-site through direct contact of waste with groundwater is not evaluated in the HELP analysis. The output of the HELP Model should be used as an "order of magnitude" estimate for evaluating potential site impacts and leachate generation.

Table 2-1
Mass Water Balance Evaluation
Old Amherst Landfill FCSA Study

Old Amherst Landfill	Area	Surface	Allowable	Estimated Annual Totals (HELP3 Model Evaluation)						Leachate Generation
		Slope	Drainage	Precipitation	Runoff	Evapo-Trans	Lateral Drainage	Leakage through Waste		Released On-site
	(acres)	(%)	(%)	(inches)	(inches / %)	(inches / %)	(inches / %)	(cubic feet)	(GPD / Acre)	(gallons / year)
EXISTING CONDITIONS (2008)										
8-inch Silty Clay Barrier Layer	33.64	2%	100%	46.48	9.85 / 21.2%	24.01 / 51.8%	0.00 / 0.0%	1,542,368	940	11,536,913
Total Unlined Area:	33.64							1,542,368	940	11,536,913

Section 3
FCSA Drilling Program

As described in Section 1.4, twelve groundwater monitoring wells and two perimeter gas monitoring wells were installed as part of the FCSA hydrogeologic investigation to characterize the stratigraphy of the unconsolidated deposits underlying and downgradient of the site, evaluate groundwater chemistry and identifying preferential contaminant transport pathways, as well as any stratigraphic barriers to contaminant migration. Well locations are shown on the FCSA site plans.

Martin Geo-Environmental, LLC drilling company out of Belchertown, Massachusetts was contracted to install the groundwater and perimeter gas monitoring wells. Drilling activities were conducted in July and August 2008 and witnessed by a Tighe & Bond, Inc. environmental scientist. MassDEP was notified of the drilling schedule in advance.

3.1 Drilling Methods & Procedures

Three drilling methods were used for monitoring well installation; hollow stem auger (HSA) drilling, drive and wash casing drilling methods and mud-rotary drilling (for well #5-08).

3.1.1 Hollow Stem Auger (HSA) Drilling

Shallow groundwater monitoring wells that are screened across the water table and the gas monitoring wells were installed using standard 4.25-inch inside diameter hollow stem auger (HSA) drilling methods and a truck mounted rotary drilling machine.

Hollow-stem auger (HSA) drilling methods involve the rotary advancement of 5-foot lengths of HSA casing into the ground. A "rod plug" is typically used at the auger cutting head below grade to minimize the accumulation of soils within the HSA casing. Standard Penetration Test (SPT) soil samples were collected at the bottom of the HSA casing prior to rotary advancing another 5-foot length of HSA casing into the ground. Monitoring wells were installed within the open HSA casing once a boring was completed. The HSA casing is slowly extracted as the well is constructed, backfilled and completed.

3.1.2 Drive & Wash Casing Drilling

Deep monitoring wells installed into the confining layer, confined aquifer or shallow bedrock were installed using standard drive and wash drilling methods using 4-inch flush threaded steel casing and a truck mounted drilling machine.

Drive and wash casing drilling methods involved the driving of a 4-inch diameter 5-foot length of steel casing into the ground using a 300-lb. hammer, and then flushing the accumulated soils out of the casing using a roller bit and clean water. Standard Penetration Test (SPT) soil samples were collected at the bottom of the casing prior to driving another 5-foot length of steel casing into the ground. The casing was slowly extracted as the well was constructed, backfilled and grouted.

For bedrock well #4-08, three 5-foot rock cores were collected using a NQ-size core bit (1.87-inch diameter) and double-tube core barrel. Once the rock cores were collected, the rock borehole was reamed to a nominal 4-inch diameter using a roller bit prior to monitoring well installation.

3.1.3 Mud Rotary Drilling

The deep bedrock monitoring well #5-08 installed at the landfill site was completed using mud rotary drilling methods using a 6-inch welded steel casing and a truck mounted mud rotary drilling machine. The mud rotary drilling method is a standard method used for the installation of private residential water supply wells where a 6-inch casing is advanced through unconsolidated materials and seating into solid bedrock at which point the borehole is advanced as an "open hole" through rock until a target depth is reached or sufficient water bearing fractures are intersected for a domestic residential water supply.

For this project, mud rotary drilling methods involved the driving of 6-inch diameter 20-foot lengths of steel casing into the ground, then flushing the accumulated soils out of the casing using a roller bit and clean water prior to welding another 20-foot casing length and repeating the process. Once solid bedrock was penetrated with the 6-inch casing, the borehole was advanced another 50 feet into rock. The well was completed by flushing out the borehole and casing, then leaving the casing in the ground as 6-inch diameter "open-hole" bedrock well.

Standard Penetration Test (SPT) soil samples or bedrock cores were not collected during mud rotary drilling at bedrock monitoring well #5-08.

3.1.4 Soil Sampling Procedures

Soil samples were collected during monitoring well installation using split spoon samplers in accordance with ASTM standard procedures for Standard Penetration Tests (SPTs). Soil samples were collected at each location in 2-foot increments at 5-foot intervals. Recovered soils were classified and described in the field using the Burmister System and recorded on the boring logs provided in Appendix G.

Soil samples were collected during monitoring well installation using split spoon samplers in accordance with ASTM method D1586-99 for Standard Penetration Tests (SPTs). Soil samples were collected at each location in 2-foot increments at 5-foot intervals. Recovered soils were classified and described in the field using the Burmister System; and recorded on the boring logs provided in Appendix F. Portions of each soil sample were retained and jarred for soil headspace screening.

3.1.5 PID Headspace Soil Screening

A portion of each soil sample was placed in a clean glass jar and screened for the presence of volatile organic compounds (VOCs) using a 10.2 eV photoionization detector (PID). The soil screening was performed in general accordance with methods described in Appendix A of MassDEP Policy #WSC-402-96.

PID readings for all soil boring samples were non-detect for VOCs. No petroleum or solvent-type odors were noted in any of these samples.

3.1.6 Water Supply for Drilling

Potable water for equipment cleaning and drilling was either obtained from a potable water source at the Amherst Transfer Station on Belchertown Road or brought to the site by the drilling contractor.

3.1.7 Disposal of Drilling Cuttings

Drilling cuttings consisting of soil removed or washed out of the borehole were collected and deposited in the vicinity of the monitoring well locations. Waste materials were not encountered at any of the boring locations.

3.1.8 Equipment Decontamination

Drilling equipment was decontaminated between boring locations by removing gross contamination such as soil cuttings, followed by rinsing with a hose. Drilling tools were generally steam cleaned at the contractor's equipment garage at the end of the day on a daily basis, or on-site. Drilling equipment was cleaned near where the respective monitoring wells were installed.

3.2 Monitoring Well Installation

Groundwater monitoring wells were installed in accordance with the standard procedures for monitoring well installation as described in *MassDEP Publication WSC-310-91, Standard References for Monitoring Wells*. In summary, monitoring wells were completed with two-inch diameter; Schedule 40, PVC riser and a 10-foot, 0.010-inch slotted well screen with flush-joint threads. No glues or additives were used during the installation. Clean washed No. 2 sand was backfilled around and two feet above the screen with a bentonite seal placed above the sand. Well construction details are included on contractor boring logs provided in Appendix F.

For all monitoring wells, riser pipes were extended 2 to 3 feet above grade and equipped with a locking protective steel casing cemented at the surface. For 2-inch PVC monitoring wells, each well was also provided with a 2 inch diameter expansion cap on the PVC pipe.

3.2.1 Gas Monitoring Wells

Gas monitoring wells PGW-8 and PGE-9 installed for the FCSA study were installed to a depth of 15 feet below grade and screened from 5 to 15 feet below grade in the vadose zone.

3.2.2 Shallow Monitoring Wells

The well screen was set in the surficial aquifer for shallow (water table) monitoring wells. In general, the well screen was set 8 feet into the groundwater table except where a high water table close to the ground surface prevented it. In the case of a high water table, the well screen was set at a depth of 15 feet below grade.

3.2.3 Deep Monitoring Wells

Deep monitoring wells installed for the FCSA study were screened in a confined aquifer or at the bottom of the confining layer that underlies the surficial aquifer downgradient of the site. The confining layer consists of fine grained glaciolacustrine deposits of fine sands, silts and clays below which at some locations is a confined aquifer of permeable sands followed by glacial till and/or bedrock.

For deep well installation, the well screen was set in the confined aquifer where encountered and sand packed to 2 feet above the top of the well screen followed by a minimum 2-foot bentonite seal tremied into the casing annulus. At each deep well, the casing annulus below the water table and above the bentonite seal was tremie grouted with a 10%/90%, bentonite/cement grout to above the top of the groundwater table, and in general to the ground surface.

3.2.4 Bedrock Wells

Bedrock well #4-08 was completed as a 2-inch diameter PVC monitoring well installed in a nominal 4-inch rock borehole and screened at a depth of 83-93 feet below grade in bedrock.

Bedrock well #5-08 was completed as a 6-inch diameter "open-hole" bedrock well at a depth of 158-210 feet below grade.

3.2.5 Well Development

Each groundwater monitoring well installed for the FCSA study was developed by repeated evacuation of the well using a trash pump or foot pump by the well installation contractor. Well development was conducted until at least 50 gallons of water was removed from each well. During well development, Tighe & Bond collected water samples for field screening of VOCS with the PID instrument. No VOCs were detected in the well development water. Given the absence of indicators of contamination (e.g. odors, VOC detections), groundwater removed during development was discharged to the surface at each well location.

3.3 Grain Size Analyses

Grain size gradation curves were prepared in accordance with *Massachusetts Solid Waste Regulation 310 CMR 19.104(3b)5h* for the screened intervals of the shallow groundwater monitoring wells. In addition, soil samples were analyzed for grain size characterization from the distinct strata in the deep monitoring wells and the deep well screen zones. A total of seventeen soil samples were submitted for grain size characterization, which included:

Well Boring	Sample Depth (feet)	Soil Classification
#1-08	15-17	Surficial Aquifer - Well screen interval
#2-08	80-82	Surficial Aquifer - Well screen interval
#3-08	80-82	Surficial Aquifer - Well screen interval
#4-08	48-50	Confined Aquifer
#6-08	25-27	Confining Layer
#6-08	45-47	Confined Aquifer - Well screen interval
#6-08	51-53	Glacial Till
#7-08	10-12	Confining Layer – Well screen interval
#8-08	10-12	Surficial Aquifer - Well screen interval
#9-08	95-97	Confining Layer
#9-08	125-127	Confining Layer – Well screen interval
#10-08	10-12	Surficial Aquifer – Well screen interval #11-08
#10-08	45-47	Confining Layer
#10-08	85-87	Confined Aquifer – Well screen interval
#12-08	10-12	Surficial Aquifer – Well screen interval #1-03
#12-08	45-47	Confining Layer
#12-08	55-57	Confined Aquifer - Well screen interval

The soil samples were submitted to GeoTesting Express in Boxborough, Massachusetts for grain size analysis by the ASTM D 422 method. The grain size analysis report is provided in Appendix G.

3.4 Hydraulic Conductivity Testing

Hydraulic conductivity tests were conducted on FCSA groundwater monitoring wells and select existing monitoring wells and test wells to determine the range of hydraulic conductivity of the stratigraphic units in the vicinity of the landfill site. This information, along with measured groundwater elevations in the monitoring wells, was used to estimate groundwater flow rates and potential contaminant migration velocity downgradient of the site. In-situ hydraulic conductivity tests were conducted in September 2008.

3.4.1 Test Methods

The hydraulic conductivity tests were conducted by instantaneously raising (falling head test) or lowering (rising head test) the water level in a monitoring well by introducing or removing a solid PVC cylinder, then recording the changes in water elevation. The PVC cylinder was decontaminated between tests at individual monitoring wells.

The 5-foot, 1.5-inch diameter solid PVC cylinder used for the testing provided a head displacement equivalent to 2.81 feet of head change in a 2-inch groundwater monitoring well. The tests were conducted by recording water levels and the elapsed time following the introduction or withdrawal of the cylinder using a pressure transducer and data logging system. Rising and falling head tests were performed in both shallow and deep monitoring wells. Following completion of the field-testing, the test data was downloaded to a computer for reduction and analysis.

3.4.2 Test Results

The hydraulic conductivity test data was analyzed using AQUIFER WIN32, a groundwater modeling software program developed by Environmental Simulations Inc. Analysis methods used to determine measured hydraulic conductivity included the *Bouwer & Rice Method* (Water Resources Research, Vol. 12, No. 3) for unconfined aquifers and the *Cooper, Bredehoff, Papadapulas Method* (Water Resources Research, Vol. 3, No. 1) for confined aquifers. Some of the confined aquifer well data and the bedrock well data were evaluated using the unconfined aquifer solution based on the field data. Hydraulic conductivity data sheets are provided in Appendix H with test results summarized in Table 3-1. Due to inherit limitations in methodology for the falling head test for wells screened across the groundwater table interface, reported hydraulic conductivities for the shallow wells are based on the rising head slug test data. Hydraulic conductivities for wells screened well below the water table are generally based on the falling head test data.

- **Surficial Aquifer (Shallow Monitoring Wells):** The hydraulic conductivity of the surficial aquifer varies from 0.2 feet per day (ft/day) in fine sands and silt to 110 ft/day in coarser soil materials (sands and gravel).

- **Confining Layer (Shallow & Deep Monitoring Wells):** The hydraulic conductivity values for monitoring wells that are screened within confining layer type soil materials of very fine sand, silt and clay ranged from about 2-10 feet per day at wells #7-08, #9-08 and #6-89.

- **Confined Aquifer (Deep Monitoring Wells):** The hydraulic conductivity values for the confined aquifer ranged from 5-35 ft/day at wells #6-08, 10-08 and #3-68.

- **Bedrock Aquifer (Bedrock Monitoring Wells):** The hydraulic conductivity values for the bedrock aquifer ranged from about 0.1 ft/day at well #4-08 to 6 ft/day at well #5-08.

3.4.3 Comparison to Grain Size Analyses

The hydraulic conductivity of the underlying soils was also estimated using the grain size data discussed in Section 3.3 and provided in Appendix G. The hydraulic conductivity of the soils was estimated using "Hazen's Equation" which is based on the "d10" fraction of soils finer than 10 percent of the individual soil sample. This evaluation is provided as Table 3-2, along with estimated hydraulic conductivities from the in-situ tests. The Hazen Equation is most appropriate for the evaluation of well-sorted, clean sandy soils.

Comparison of the estimated hydraulic conductivities from the grain size data versus the in-situ testing generally indicates a poor correlation between the estimated grain size hydraulic conductivities and the observed in-situ test results. For coarser sandy soils such as the surficial aquifer at the landfill site and some of the confined aquifer wells, the in-situ data exhibits a significantly lower hydraulic conductivity than that estimated with the grain size data. This is attributed to the presence of varying amounts of fine to very fine sands in the screen zone of the monitoring wells.

TABLE 3-1
Hydraulic Conductivity Test Results
Old Amherst Landfill, Amherst, Massachusetts

Well ID	Test Type	Screen Depth (feet)	Hydraulic Conductivity ft/day	Hydraulic Conductivity cm/sec	General Soil Classification at Screen Zone
1-08	Rising Head Test	8-18	12.97	4.58E-03	Surficial Aquifer: medium-coarse Sand, some Gravel
1-08	Falling Head Test	"	7.85	2.77E-03	"
2-08	Rising Head Test	73-83	0.24	8.47E-05	Surficial Aquifer: fine Sand, trace Silt
2-08	Falling Head Test	"	2.83	9.98E-04	
3-08	Rising Head Test	83-73	5.31	1.87E-03	Surficial Aquifer: medium-coarse Sand, little Gravel
3-08	Falling Head Test	"	6.41	2.26E-03	"
4-08	Rising Head Test	83-93	0.18	6.35E-05	Bedrock Aquifer: Arkosic Sandstone (bedrock)
4-08	Falling Head Test	"	0.13	4.59E-05	"
5-08	Rising Head Test	158-210	5.84	2.06E-03	Bedrock Aquifer: open borehole in bedrock (Arkosic Sandstone)
5-08	Falling Head Test		6.24	2.20E-03	"
6-08	Rising Head Test	40-50	5.91	2.08E-03	Confined Aquifer: fine-medium Sand
6-08	Falling Head Test	"	4.96	1.75E-03	"
7-08	Rising Head Test	5-15	9.45	3.33E-03	Confining Layer: Clay, trace Silt
7-08	Falling Head Test		23.21	8.19E-03	"
8-08	Rising Head Test	5-15	16.45	5.80E-03	Surficial Aquifer: very fine-fine Sand, trace Silt
8-08	Falling Head Test	"	6.71	2.37E-03	"
9-08	Rising Head Test	121-131	2.54	8.96E-04	Confined Aquifer: very fine Sand, little Silt, trace Clay
9-08	Falling Head Test	"	3.35	1.18E-03	"
10-08	Rising Head Test	80-90	3.29	1.16E-03	Confined Aquifer: very fine-medium Sand
10-08	Falling Head Test	"	8.24	2.91E-03	"
11-08	Rising Head Test	4-14	23.52	8.30E-03	Surficial Aquifer: very fine-fine Sand
11-08	Falling Head Test	"	23.16	8.17E-03	"
12-08	Rising Head Test	47-57	2.31	8.15E-04	Surficial Aquifer: very fine Sand & Silt
12-08	Falling Head Test	"	2.42	8.54E-04	"
PGW-3	Rising Head Test	15-35	5.15	1.82E-03	Surficial Aquifer: very fine Sand, trace Silt
PGW-3	Falling Head Test	"	0.87	3.07E-04	"
PGW-4	Rising Head Test	5-20	107.93	3.81E-02	Surficial Aquifer: fine to medium Sand, trace Silt
PGW-4	Falling Head Test	"	21.78	7.68E-03	"
1-03	Rising Head Test	5-15	0.48	1.69E-04	Surficial Aquifer: very fine Sand & Silt (see #12-08 boring log)
1-03	Falling Head Test	"	0.77	2.72E-04	"
2-03	Rising Head Test	8-18	7.37	2.60E-03	Surficial Aquifer: fine to coarse Sand & Gravel
2-03	Falling Head Test	"	77.14	2.72E-02	"
5-89	Rising Head Test	62-72	9.66	3.41E-03	Surficial Aquifer: fine to coarse Sand & Gravel
5-89	Falling Head Test	"	23.64	8.34E-03	
6-89	Rising Head Test	150-160	2.45	8.64E-04	Confining Layer: very fine Sand, Silt & Clay
6-89	Falling Head Test	"	3.15	1.11E-03	
3-68	Rising Head Test	39-49	36.42	1.28E-02	Confined Aquifer: fine-coarse Sand & Gravel
3-68	Falling Head Test	"	32.78	1.16E-02	"

TABLE 3-2
Grain Size & Hydraulic Conductivity Estimates
Old Amherst Landfill FCSA Study
Amherst, MA

Monitoring Well #	Depth (feet)	Aquifer Classification	Grain Size Distribution			Estimated Hydraulic Conductivity (Hazen's Equation) K = A(d10)2 A = 1.0			HC Test Data (feet/day)
			Sieve < #200 %	Hydrometer < 2 microns %	d10 (mm)	K (cm/s)	Soil Description (Geotechnical laboratory)	K (feet/day)	
UPGRADIENT "BACKGROUND" MONITORING WELL									
Well #1-08 (Screen Zone)	15-17	Surficial Aquifer	3		0.2895	8.4E-02	Yellowish Brown Sand and Gravel ASTM Poorly Graded Sand with Gravel (SP)	2851	12.97
LANDFILL & DOWNGRADIENT MONITORING WELLS									
Well #2-08 (Screen Zone)	80-82	Surficial Aquifer	2		0.1419	2.0E-02	Grayish Brown Sand ASTM Poorly Graded Sand (SP)	685	0.24
Well #3-08 (Screen Zone)	80-82	Surficial Aquifer	4		0.1335	1.8E-02	Yellowish Brown Sand ASTM Poorly Graded Sand (SP)	606	5.31
Well #4-08	48-50	Confined Aquifer	4		0.2321	5.4E-02	Yellowish Red Sand ASTM Poorly Graded Sand (SP)	1832	
Well #6-08	25-27	Confining Layer	98	23	0.0012	1.4E-06	Gray Silty Clay ASTM N/A	0.049	
Well #6-08 (Screen Zone)	45-47	Confined Aquifer	5		0.1094	1.2E-02	Dark Olive Brown Sand with Gravel (ASTM Poorly Graded Sand with Gravel (SP)	407	4.96
Well #6-08	51-53	Glacial Till	13	1	0.0460	2.1E-03	Reddish Brown Silty Gravel with Sand ASTM N/A	72	

TABLE 3-2
Grain Size & Hydraulic Conductivity Estimates
Old Amherst Landfill FCSA Study
Amherst, MA

Monitoring Well #	Depth (feet)	Aquifer Classification	Grain Size Distribution			Estimated Hydraulic Conductivity (Hazen's Equation) K = A(d10)2 A = 1.0			HC Test Data (feet/day)
			Sieve < #200 %	Hydrometer < 2 microns %	d10 (mm)	K (cm/s)	Soil Description (Geotechnical laboratory)	K (feet/day)	
Well #7-08* (Screen Zone)	10-12	Confining Layer	99	58	0.0010	1.0E-06	Olive gray Clay ASTM N/A	0.034	9.45
Well #8-08 (Screen Zone)	10-12	Surficial Aquifer	59	1	0.0194	3.8E-04	Yellowish Brown Sandy Silt ASTM N/A	13	16.45
Well #9-08	95-97	Confining Layer	84	2	0.0093	8.6E-05	Gray Silt with Sand ASTM N/A	2.9	
Well #9-08 (Screen Zone)	125-127	Confining Layer	76	3	0.0100	1.0E-04	Olive Brown Silt with Sand ASTM N/A	3.4	3.35
Well #10-08 (#11-08 Screen Zone)	10-12	Surficial Aquifer	11	1	0.0659	4.3E-03	Yellowish Brown Sand with Silt ASTM N/A	148	23.52
Well #10-08	45-47	Confining Layer	98	8	0.0027	7.3E-06	Dark Gray Silt ASTM N/A	0.25	
Well #10-08 (Screen Zone)	85-87	Confined Aquifer	10	1	0.0752	5.7E-03	Dank Gray Sand with Silt ASTM N/A	192	8.24
Well #12-08 (#1-03 Screen Zone)	10-12	Confining Layer	88	7	0.0026	6.8E-06	Light Olive Brown Silt ASTM N/A	0.23	0.48
Well #12-08	45-47	Confining Layer	71	1	0.0187	3.5E-04	Grayish Brown Silt with Sand ASTM N/A	12	
Well #12-08 (Screen Zone)	55-57	Confining Layer	63	1	0.0166	2.8E-04	Gray Sandy Silt ASTM N/A	9	2.30

* d10 fraction <0.001 mm; calculated hydraulic conductivity is lower than this estimate

Section 4
Site Hydrogeology

The CSA investigations were conducted to characterize the hydrogeology and groundwater flow patterns at the Old Amherst Landfill and to investigate downgradient water quality impacts to the surficial and confined aquifers.

A review of USGS mapped site hydrogeology and previous studies were provided in the June 2004 ISA Report. For reference, the ISA Report information is summarized in Sections 4.1 and 4.2 below.

4.1 Regional Hydrogeology

Regional geologic mapping has been conducted by the US Geological Survey (USGS) for the Belchertown, Massachusetts $7^1/_2$ minute Quadrangle and surrounding area. Regional bedrock and surficial mapping is available for the Quadrangle in other USGS and state resources as follows:

4.1.1 USGS Hydrogeologic Atlas HA-563

Regional scale groundwater aquifer mapping is available for the Belchertown, MA. Quadrangle as USGS Hydrogeologic Investigations Atlas HA-563 titled Map Showing Availability of Ground Water in the Connecticut River Lowlands, Massachusetts, by Eugene H. Walker and William W. Caswell, 1979, 2 plan sheets.

Plan Sheet 2 of the report indicates that the Old Amherst Landfill overlies unconsolidated deposits of sand and gravel with potential well yields of 25 – 1,000 gallons per minute (gpm). The sand and gravel deposits include the three primary types of water supply aquifers. Bedrock aquifers are differentiated into Triassic age and Pre-Triassic age units. Identified aquifers are noted below along with the relation to the site.

4.1.1.1 Surficial Lowland Aquifer

A surficial layer of sand and gravel deposited on floodplains and low-land river terraces that yields up to 50 gpm to individual wells.

The majority of the site is shown as overlying a sand and gravel aquifer unit consisting of the surficial lowland aquifer and possibly a deeper confined aquifer.

4.1.1.2 Confined Sand and Gravel Aquifer

A basal layer of sand and gravel deeply buried under lacustrine deposits that yield up to 1,000 gpm where present.

The presence or absence of this aquifer is not delineated on the mapping.

4.1.1.3 Marginal Sand and Gravel Deposits

Sand and gravel deposits that are finer grained or thinner that occur along aquifer margins abutting bedrock or till hillsides. Yields in this deposit are reported as generally less than 25 gpm.

This unit is mapped along the eastern portion of the landfill site bordering bedrock.

4.1.1.4 Triassic Age Bedrock Aquifer

The Triassic bedrock aquifer unit is described as sandstones, shales, conglomerates and diabase (basalt) rock of Triassic age (205-240 million years old) bedrock of the Connecticut Valley.

The reported yields of water supply wells in the Triassic bedrock are variable, reportedly in the range of 10 - 100 gpm. Well yields of Triassic age rock located below the sand and gravel aquifers are reported to typically yield 50 gpm with a maximum reported yield of 700 gpm.

The so-called Eastern Border Fault which delineates the easternmost deposits of Triassic age bedrock is mapped to the south of the landfill site. The landfill is inferred to overlie Pre-Triassic age bedrock.

4.1.1.5 Pre-Triassic Age Bedrock Aquifer

The Pre-Triassic age bedrock unit is described as undifferentiated metamorphic and igneous rock greater than Triassic age. Well yields are reported as up to 10 gpm with higher yields (up to 50 gpm) possible where the bedrock is covered by saturated sands and gravels or near streams.

4.1.2 USGS Miscellaneous Investigations I-1074

Regional 1:125,000 scale mapping of unconsolidated materials is available for the Belchertown, MA. Quadrangle as USGS Miscellaneous Investigations Series I-1074 of the Connecticut Valley Urban Area, Central New England, 1979, by Janet Radway Stone, Elizabeth Haley London, and William H. Langer. Three of the series maps show information relevant to the ISA and CSA studies:

4.1.2.1 Map I-1074-B: Textures of Unconsolidated Materials

Map I-1074-B indicates that the landfill site overlies sand and gravel deposits. Three areas of "artificial fill (af)" are shown on the site that indicates areas were wastes were deposited in the landfill.

4.1.2.2 Map I-1074-C: Distribution & Thickness of Fine-Grained Deposits

Map I-1074-C indicates that the landfill site overlies 0-50 feet of fine grained sediments deposited in a glacial lake (glaciolacustrine deposits).

4.1.2.3 Map I-1074-I: Groundwater Availability – Northern CT. Valley Area

Map I-1074-I portrays the landfill site as overlying aquifer deposits capable of yielding 1-1,000 gpm. The mapping indicates that surficial sand and gravel deposits in lowland areas and river terraces typically yield less than 25 gpm with buried sand and gravel deposits yielding as much as 1,000 gpm.

The mapping also indicates that the landfill site overlies metamorphic bedrock such as schist or gneiss that yields low quantities (1-100 gpm) of groundwater from open fractures.

4.2 Site Hydrogeology

Bedrock and surficial geologic quadrangle maps ("GQ" Maps) have not been finalized for the Quadrangle. However, the geology of the Quadrangle has been mapped by the USGS and the preliminary mapping is available as USGS Open File Report OF-77-633. MassGIS mapping is also available for the site that shows the relation of the landfill to delineated aquifer areas and other environmental considerations such as wetlands and rare wildlife areas.

4.2.1 USGS Open File Report OF-77-633

Preliminary geologic mapping is available for the Belchertown, MA Quadrangle as USGS Open File Report OF-77-633 titled Surficial and Applied Surficial Geology of the Belchertown Massachusetts Quadrangle, by J. A. Caggiano, Jr., 1977, and includes 122 pages, 5 plates, 12 figures, 5 tables. The report is an extensive evaluation of the complex geology of the Quadrangle as related to Pleistocene deglaciation and the later deposits of Glacial Lake Hitchcock.

The five plates (maps) included in the Report are entitled:

- Plate 1 – Surficial Geologic Map
- Plate 2 – Materials Map
- Plate 3 – Thickness of Drift
- Plate 4 – Depth to Varved Clay
- Plate 5 – Thickness of Varved Clay

USGS Open File Report OF-77-633 also includes as Figure 2 a "Generalized Bedrock Geologic Map" of the Quadrangle based on a preliminary evaluation of mapped bedrock outcrops.

4.2.1.1 Plate 1 - Surficial Geologic Map

The Old Amherst Landfill site is delineated on the map legend as "Boundary of Municipal Landfill Site" and contains three (3) distinct areas delineated as "aft or artificial fill trash". The site is mapped as overlying undifferentiated glaciofluvial deposits (Qch) located north of the Holyoke Range. The map indicates that sand and gravel deposits were mapped at the site in bank cuts that exposed the glaciofluvial deposits. These deposits consist of sands, gravels and silts deposited by melt water action in temporary streams and lakes during deglaciation. Landforms include outwash plains, kames, kame terraces, kame deltas and ice channel fillings deposited by fluvial processes.

Deposits mapped immediately to the west, northwest and southwest of the site are mapped as Shoreward Deposits of Glacial Lake Hitchcock (Qlhs), consisting of moderate to well sorted sands and gravels, not including lacustrine (lake) deposits. Lacustrine Deposits are mapped further west of the site along the valley floor and consist of well sorted and stratified sands with minor amounts of gravel and silt.

4.2.1.2 Plate 2 - Materials Map

The landfill site is identified on Plate 2 as containing the three (3) distinct areas delineated as "aft or artificial fill trash", as described for Plate 1. The majority of the site is mapped as "g or gravel" with the southwestern quarter mapped as overlying "s or sand. The sand is described as generally moderately to well sorted and frequently containing pebbles and cobbles in varying amounts.

4.2.1.3 Plate 3 - Thickness of Drift

The thickness of unconsolidated sediments in the vicinity of the landfill site is identified between 45 to 75 feet east of the site to 107 to 112 feet west of the site.

4.2.1.4 Plate 4 - Depth to Varved Clay

No varved clay is mapped at the Old Amherst Landfill or in the immediate vicinity of the site.

4.2.1.5 Thickness of Varved Clay

No varved clay is mapped at the Old Amherst Landfill or in the immediate vicinity of the site.

4.2.1.6 Generalized Geologic Map

Figure 2 of the Open File Report titled Generalized Bedrock Map indicates that the landfill is located above "Arkosic Conglomerate and Sandstone of the Connecticut Valley Lowland". Otherwise, detailed bedrock mapping is not provided in the Open File Report.

The report text indicates that the so-called eastern border fault of the Connecticut River Valley is not mapped in the vicinity of the landfill due to the lack of exposed bedrock whereas the bedrock mapping indicates that the Triassic / Pre-Triassic bedrock contact is to the east of the site at the base of the bordering uplands.

4.2.1.7 Environmental Geology - Landfill Discussion

The Open File Report contains a discussion on the potential landfill impact to the groundwater quality at the former Brickyard Well Field. The report notes that the Brickyard Well Field is located approximately 2,500 west and 90 feet lower in elevation than the landfill site. The report also notes that the landfill is located on highly permeable glaciofluvial sands and gravel, and that low permeability material that would be capable of retarding the movement of leachate from the landfill is absent from the sediments underlying the landfill site. The landfill is reported to be in the recharge area for the Lawrence Swamp Aquifer, the Town of Amherst's principle groundwater supply source.

The Open File Report indicates that the groundwater quality at the Brickyard Well Field was impacted by slight increases in chloride levels. The report also indicated that subsequent water quality testing (circa 1972) at the Brickyard Well Field exhibited slight increases in hardness and sulfates, following which the Town drilled additional test wells at other locations in the aquifer.

4.2.2 MassGIS Mapping

Environmental database mapping is available for the site vicinity through MassGIS, a State run GIS mapping service. The map, titled MassGIS Mapping at a scale of 1"=500' is provided in Appendix B. The Mass GIS Mapping shows the relation of the landfill to delineated aquifer areas and other environmental considerations such as wetlands and rare wildlife areas.

4.2.2.1 MassGIS - Aquifer Areas & Zone II

The Mass GIS Mapping indicates that the landfill site overlies a delineated "Potentially Productive Medium Yield Aquifer" area, generally defined as an aquifer with a potential yield of 50 gpm to 300 gpm. Also, the Zone II area for the current Town water supply wells is shown as extending to 300 feet south of the landfill site.

4.2.2.2 MassGIS - Rare Wildlife Areas

The MassGIS mapping also indicates that the abutting property to the east of the landfill site that contains ponds and wetlands is designated as a "priority habitat" by the Massachusetts Natural Heritage and Endangered Species Program (NHESP).

4.3 Groundwater & Surface Water Flow

Groundwater elevations are used to determine shallow horizontal groundwater gradients across and downgradient of the site. This information, used in conjunction with the surficial aquifer hydraulic conductivity data, allows estimation of groundwater flow velocities in the surficial aquifer.

Groundwater elevations at individual monitoring well clusters were also used to evaluate vertical groundwater flow gradients at the site.

4.3.1 Surface Water Flow

Overall surface water flow in the vicinity of the site is east to west towards Hop Brook and the Hop Brook flood plain and associated wetland areas that are located to the west of the Old Amherst Landfill site. Hop Brook flows south to north in its flood plain and discharges to the Fort River at a location approximately 1-mile northwest of the landfill. The primary drainage area for Hop Brook is the Lawrence Swamp basin located approximately 1-mile south of the landfill site. The Lawrence Swamp basin the primary groundwater supply source for the Town of Amherst where a series of high-yield water supply wells were developed in a confined aquifer that consists of a basal deposit of permeable sands and gravel. The confined aquifer in the Lawrence Swamp basin underlies thick glaciolacustrine deposits of very fine sands, silts and clays and is under artesian conditions at various locations.

Surface water drainage at the closed landfill site is primarily to the east and south, towards Pomeroy Pond to the east and towards a large retention to the south. The retention area was constructed as part of the landfill closure project in the early 1980s and was a former borrow area for cover materials during the operation of the landfill.

4.3.2 Groundwater Elevations

Site groundwater elevations were measured twice for the FCSA study, once on August 28, 2008 and again during groundwater sampling in October 2008 for various wells. Groundwater elevation data is summarized on Table 4-1. This table also includes information on well depth, screen depth, screen length and characterization of the screened aquifer unit taken from boring and well installation logs.

Groundwater elevations were measured using an electronic water level measuring device. Measurements to the groundwater level in each well were referenced to the top of the PVC well casing, a surveyed point. Water level depths were converted to groundwater elevations using surveyed well elevations.

4.3.3 Groundwater Flow Directions

Groundwater elevation data collected in August 2008 were used to construct the August *2008 Groundwater Contour Plan* provided in Appendix A. To supplement the groundwater elevation data, surface water and wetland spot elevations were estimated and used to prepare the groundwater contour mapping.

The August 2008 groundwater contours show an overall western groundwater gradient and flow direction across the site. The groundwater flow direction is also projected to the west, north and south of the site. Based on this mapping and as concluded in the ISA Report, groundwater flow from the landfill is not projected to the south of monitoring well #1-03. The groundwater table gradient is steepest at the landfill site adjacent to Pomeroy Pond between gas monitoring wells PGW-4 and PGW-5, flattening to the west of the landfill towards groundwater discharge areas at Gull Pond, the KC Trail wetland and wetlands near the SW-15 surface water station adjacent to the intersection of Old Farm Road and Hop Brook Drive.

4.3.4 Groundwater Flow Rates

The horizontal flow velocity was calculated for the surficial aquifer using the formula V=Ki/n, where:

- V = horizontal groundwater flow velocity
- K = hydraulic conductivity
- i =horizontal flow gradient (ft/ft)
- n = a unit less number that represents the porosity of soils.

The FCSA Groundwater Contour Plan was used to estimate shallow horizontal groundwater flow gradients across the site for the August 2008 groundwater elevation monitoring event. Groundwater flow rates were estimated using the shallow groundwater flow gradients, measured hydraulic conductivities in the surficial aquifer and an estimated porosity in the surficial aquifer of 0.35 for void area in the soils, typical of silty sands (*Freeze, R.A and J.A. Cherry. 1979 Groundwater, Prentice-Hall, New Jersey*).

Estimated groundwater flow rates are equivalent to contaminant transport velocities for conservative contaminants, such as chloride, that do not readily adsorb to soil particles or biodegrade. Other contaminants such as metals or VOCs can be adsorbed, chemically altered to less mobile forms or degraded in the groundwater system and may have lower transport velocities. Also, the fluctuation of groundwater gradients due to seasonal conditions will affect flow velocities; these conditions were not evaluated.

4.3.4.1 Landfill Site

Estimated shallow groundwater flow gradients across the landfill site based on the August 2008 groundwater elevation gauging event varied from about 0.10 feet per foot at the south end of the site to about 0.03 feet/foot in the central and northern portion of the site. Using the southern horizontal gradient of 0.10 feet/foot paired with a representative hydraulic conductivity of the surficial aquifer of 10 feet/day, the shallow horizontal groundwater flow velocity is about 3 ft/day, or about 1,100 feet per year. For the central and northern portions of the site, using an average horizontal gradient of 0.03 feet/foot and representative hydraulic conductivity of the surficial aquifer of 10 feet/day, the calculated shallow horizontal flow is about 1 ft/day, or about 365 feet per year.

4.3.4.2 Downgradient of the Landfill Site

Based on the August 2008 and previous November 2005 Groundwater Contour Plans prepared for the landfill site, the groundwater table flattens downgradient of the landfill under the Amherst Woods and Amherst Fields residential developments. Using a representative shallow horizontal gradient of 0.015 feet /foot and representative surficial aquifer hydraulic conductivity of 10 feet/day, the calculated shallow horizontal groundwater flow fate is about 0.4 ft/day, or about 150 feet per year.

Evaluation of potential contaminant transport downgradient of the Old Amherst Landfill area using this data indicates that the time necessary for a conservative contaminant to discharge to seepage areas downgradient of the site is approximately 11 years for the KC Trail wetland area.

4.4 Geologic Cross Sections

Geologic cross sections were prepared to graphically evaluate the underlying stratigraphy, identify principal aquifer and confining units, and characterize contaminant migration pathways in the subsurface. The cross section lines are shown on the FCSA Groundwater Contour Plan and are provided on a Geologic Cross Sections Plan provided in Appendix B.

Four geologic cross sections were prepared for the FCSA Report using information obtained from boring and well installation logs. Cross Sections A, B and C are oriented roughly east to west across the Old Amherst Landfill to wetlands located to the west of the Amherst Woods and Amherst Fields housing developments. Cross Section D is roughly oriented south to north from Station Road to Gull Pond. The geologic cross sections are described as follows:

4.4.0.1 Cross Section A

Cross Section A extends from the Gull Pond monitoring well cluster #6-08/#7-08 across the landfill to upgradient well #1-08 located near the intersection of Old Belchertown Road and Larkspur Drive. The confined aquifer screened by well #6-08 is shown beneath a confining layer of silt and clay that pinches out to the east. Bedrock slopes east to west across the profile.

4.4.0.2 Cross Section B

Cross Section B extends from the KC Train monitoring well cluster #10-08/#11-08 across the landfill to upgradient well #1-08 and boring B12-84 located near the intersection of Old Belchertown Road and Belchertown Road (Route 9). The confined aquifer screened by well #10-08 is shown beneath a confining layer of very fine sand, silt and clay that pinches out to the east. Bedrock slopes east to west across the profile.

4.4.0.3 Cross Section C

Cross Section C extends from monitoring well cluster #8-08/#9-08 located at the intersection of Old Farm Road and Hop Brook Drive across the landfill to upgradient well #1-08 and boring B12-84.. A thin confined aquifer intersected by the boring for well #9-08 is shown beneath a thin confining layer of very fine sand and silt that pinches out to the east. Bedrock slopes east to west across the profile.

4.4.0.4 Cross Section D

Cross Section D extends from monitoring well cluster #4-83/#2-85/#4-08 located off of Station Road near the intersection with the railroad line to well cluster #1-03/#12-08 to #8-08/#9-08 to #10-08/#11-08 and terminates at well cluster #6-08/#7-08 adjacent to Gull Pond. A thin confined aquifer is shown along the bottom of a confining layer of fine grained soils (mixtures of very fine sand, silt and clay) between the #8-08/#9-08 and #6-08/#7-08 well clusters; this confined aquifer may not be contiguous between the well clusters but is shown graphically for illustrative purposes. The confined aquifer is probably located west of the #1-03/#12-08 well cluster location.

Table 4-1
Groundwater Elevation Summary
Old Amherst Landfill FCSA Study

Monitoring Well #	Well Depth (feet)	Screen Depth (feet bg)	Screened Aquifer Unit	Elevation USGS msl Ground (feet msl)	Elevation USGS msl Top Casing (feet msl)	Elevation USGS msl Top PVC (feet msl)	Groundwater Elevations (USGS feet msl) 11-Oct-05	10-Nov-05	26-Aug-08	11-Oct-08
PGW-1	45	5-45	Surficial	263.8	267.09	266.98	40.18 **226.80**	38.47 **228.51**	xxx xxx	xxx
PGW-2	45	5-45	Surficial	268.0	271.13	271.00	43.11 **227.89**	37.75 **233.25**	39.82 **231.18**	xxx
PGW-3	35	5-35	Surficial	271.5	274.80	274.66	36.80 **237.86**	28.01 **246.65**	32.97 **241.69**	xxx
PGW-4	20	5-20	Surficial	252.6	255.68	255.46	13.48 **241.98**	8.59 **246.87**	11.74 **243.72**	xxx
#11-71	62	57-62	Surficial	251.8	252.49	xxx	xxx	29.98 **222.51**	34.45 **218.04**	xxx
PGW-5	50	5-50	Surficial	242.3	245.43	245.33	46.64 **198.69**	43.44 **201.89**	44.91 **200.42**	xxx
PGW-6	88	8-88	Surficial	276.9	279.83	279.57	80.19 **199.38**	80.72 **198.85**	78.49 **201.08**	79.45 **200.12**
#5-08	210	158-210	Bedrock	277.6	279.45	xxx	xxx	xxx	76.05 **203.40**	87.82 **191.63**
PGW-7	50	5-50	Surficial	282.6	285.93	285.67	<52.60 **<233.07**	<52.6 **<233.07**	<52.73 **<233.30**	xxx
PGW-8	15	5-15	Surficial (Vadose Zone)	283.0	285.20	284.98	xxx	xxx	xxx	xxx
PGW-9	15	5-15	Surficial (Vadose Zone)	274.0	276.14	275.92	xxx	xxx	xxx	xxx
#3-68	49	35-49	Confined	173.1	173.48	xxx	xxx	4.48 **169.00**	4.87 **168.61**	4.72 **168.76**
#5-68	44	44-54	Confined	170.8	171.25	xxx	xxx	xxx	3.88 **167.37**	xxx
#6-68	50	42-50	Confined	170.8	171.70	xxx	xxx	xxx	2.98 **168.72**	xxx
#3-80	123	118-123	Confined	173.1	174.66	xxx	xxx	5.55 **169.11**	5.39 **169.27**	4.93 **169.73**
#1-83	110	105-110	Confined - Artesian	160.9	161.73	xxx	xxx	0.00 **161.73**	0.00 **161.73**	0.00 **161.73**
#2-83	98	94-98	Confined - Artesian	162.1	162.44	xxx	xxx	0.00 **162.44**	0.00 **162.44**	0.21 **162.23**
#3-83	107	102-107	Confined - Artesian	162.1	164.81	xxx	xxx	0.00 **164.81**	0.00 **164.81**	0.00 **164.81**
#2-85	40	15.5-26.6	Surficial	184.6	185.33	xxx	xxx	13.90 **171.43**	xxx xxx	xxx
#4-83	69	64-69	Weathered Bedrock	184.8	185.56	xxx	xxx	13.90 **171.66**	13.29 **172.27**	12.56 **173.00**
#4-08	93	83-93	Bedrock	184.7	186.94	186.71	xxx	xxx	14.70 **172.01**	16.12 **170.59**
#3-85	46	36-46	Confined	172.0	173.08	xxx	xxx	0.60 **172.48**	0.20 **172.88**	0.00 **173.08**
#5-89	72 +/-	62-72 +/-	Surficial	261.0	261.35	261.23	xxx	63.95 **197.28**	63.43 **197.80**	64.16 **197.07**
#6-89	160 +/-	150-160 +/-	Confining Layer	242.1	244.34	243.10	xxx	43.49 **199.61**	43.69 **199.41**	44.55 **198.55**
#1-94				163.5	165.18	xxx	xxx	xxx	xxx	xxx
#2-03	18	8-18	Surficial	266.2	268.50	268.20	xxx	9.48 **258.72**	11.41 **256.79**	11.81 **256.39**

Table 4-1
Groundwater Elevation Summary
Old Amherst Landfill FCSA Study

Tighe & Bond, Inc.

Monitoring Well #	Well Depth (feet)	Screen Depth (feet bg)	Screened Aquifer Unit	Elevation USGS msl			Groundwater Elevations (USGS feet msl)			
				Ground (feet msl)	Top Casing (feet msl)	Top PVC (feet msl)	11-Oct-05	10-Nov-05	26-Aug-08	11-Oct-08
#1-08	**18**	**8-18**	**Surficial**	274.4	276.90	276.65	xxx	xxx	12.53 **264.12**	12.36 **264.29**
#2-08	**83**	**73-83**	**Surficial** **Surficial**	282.8	285.29	285.01	xxx	xxx	77.67 **207.34**	78.21 **206.80**
#3-08	**83**	**73-83**	**Surficial**	273.8	276.10	275.83	xxx	xxx	77.60 **198.23**	78.33 **197.50**
#6-08	**50**	**40-50**	**Confined - Artesian**	173.9	176.76	181.71 (+5.00 feet)	xxx	xxx	3.25 **178.46**	0.00 **176.72**
#7-08	**15**	**5-15**	**Confining Layer**	173.9	177.10	175.82	xxx	xxx	15.42 **160.40**	10.64 **165.18**
#8-08	**15**	**5-15**	**Surficial**	179.7	182.61	182.46	xxx	xxx	8.41 **174.05**	8.29 **174.17**
#9-08	**131**	**121-131**	**Confining Layer**	179.9	182.53	182.37	xxx	xxx	8.44 **173.93**	8.21 **174.16**
#10-08	**90**	**80-90**	**Confined**	180.8	183.79	183.69	xxx	xxx	5.43 **178.26**	5.45 **178.24**
#11-08	**14**	**4-14**	**Surficial**	180.3	183.54	183.43	xxx	xxx	5.57 **177.86**	5.55 **177.88**
#1-03	**15**	**5-15**	**Surficial**	192.5	195.29	194.91	xxx	5.88 **189.03**	6.54 **188.37**	6.63 **188.28**
#12-08	**58**	**47-57**	**Surficial**	192.3	195.62	195.43	xxx	xxx	6.06 **189.37**	6.40 **189.03**

Note:
9.48 = Measured Depth to Groundwater from Top PVC or Casing
258.72 = Groundwater Elevation (USGS feet msl)

Wells are grouped as well clusters where appropriate.

Section 5
FCSA Environmental Monitoring

The CSA Report is based on two rounds of site-wide environmental monitoring, one round conducted in November 2005 for the Interim CSA Report and one round conducted in October 2008 for the FCSA study. Recommendations for post-closure environmental monitoring based on the FCSA study findings are presented in Section 7.

Environmental monitoring data previously described in the January 2006 Interim CSA Report will not be repeated for the FCSA Report with the exception of the identification of so-called "contaminants of concern (COCs)". Specifics of the FCSA environmental monitoring program are discussed in the sections below.

5.1 FCSA Monitoring Program

The CSA environmental monitoring program included the collection of groundwater, surface water and sediment samples for the analytical parameters listed in *Massachusetts Solid Waste Regulation 310 CMR 19.132(1)h* during two monitoring rounds, one for the Interim CSA study and one for the FCSA study. MassDEP was notified prior to conducting each of these events.

5.1.1 Analytical Parameters

CSA environmental monitoring parameters required under *MassDEP Solid Waste Regulations 310 CMR 19.132(1)h* are listed in Table 5-1. The following additional information pertaining to the CSA sampling and analyses is provided as follows:

- Dissolved metals analyses were conducted for groundwater and surface water samples for the FCSA water quality analyses.
- Well #1-94 was not sampled in October 2008 because the field adjacent to Hop Brook where the well is located was flooded and the well could not be found.
- Field analyses for groundwater at well #1-03 were not recorded on the field log and therefore not reported.
- Well #2-85 (surficial aquifer) was obstructed and could not be sampled during October 2008. Well #4-83 was sampled as an alternate at this location.

Lists of analytical parameters are also included on the water quality and sediment chemistry tables at the end of this Section.

5.1.2 Monitoring Stations

FCSA environmental monitoring stations are listed in Tables 5-2, 5-3, 5-4, 5-5, 5-6 and 5-7. These monitoring stations were reviewed with the MassDEP in the field prior to monitoring well installation, surface water and sediment sampling. FCSA environmental monitoring stations are shown on the FCSA Site Plans provided in Appendix A. Monitoring station locations are discussed below in further detail.

5.2 FCSA Analytical Data Summary

Environmental monitoring samples were collected twice during the completion of the FCSA study, once in May 2008 for surface water and sediment samples and a second sampling event in October 2008 for groundwater samples and additional sediment samples. Test America Laboratory (TAL) of Westfield, Massachusetts, a state-certified environmental laboratory, collected and analyzed the samples. Laboratory analytical reports are provided in Appendix I. Analytical summary spreadsheets are provided at the end of this section.

Analytical results for water samples are reported in milligrams per liter (mg/L) or micrograms per liter ug/L. Results reported in mg/L are equivalent to a level of parts per million (ppm). Results reported in ug/L are equivalent to a concentration of part per billion (ppb). Analytical results for sediment samples are reported in milligrams per kilogram (mg/kg) or micrograms per liter (ug/kg)), which are equivalent to concentrations of ppm and ppb, respectively. Data presented in this report with a "J" qualifier indicate that the contaminant was detected below laboratory reporting limit but greater or equal to the analytical method detection limits; the reported concentration is an estimated value.

As a basis for comparison, groundwater analytical data are compared to Massachusetts Maximum Contaminant Levels (MMCLs), MassDEP Office of Research & Standards Guidelines (ORSGs) and Secondary Maximum Contaminant Levels (SMCLs). MMCLs are Massachusetts's drinking water standards. ORSGs are Massachusetts drinking water guidelines established by the MassDEP Office of Research & Standards. SMCLs are equivalent to US EPA secondary drinking water guidelines and are not enforceable standards. In some cases, groundwater analytical data are also compared to MCP Reportable Concentrations and Method 1 Cleanup Standards for further reference.

Surface water analytical data are compared to Massachusetts Ambient Water Quality Criteria (AWQC) for fresh water previously listed under *310 CMR 40.1516*. The AWQC includes both "Acute" and "Chronic" criteria guidelines for some parameters. Water quality data is also compared to *Massachusetts Surface Water Quality Standards (SWQS)* promulgated under *314 CMR 4.00*.

Sediment quality is compared to *MassDEP Freshwater Sediment Screening Threshold Effects Concentrations* (TECs) in accordance with current MassDEP policy. Analytical parameters without TECs were compared to the *1993 Ontario Guidelines for the Protection of Aquatic Sediment Quality* for Lowest Effect Levels (LELS) and Severe Effect Levels (SELs). MCP Reportable Concentrations (RCs) for soils (for human health risk) are also listed for further reference.

Referenced standards are provided on the analytical summary tables provided at the end of this Section.

5.2.1 FCSA Groundwater

One round of analysis of groundwater for the parameters outlined under *Massachusetts Solid Waste Regulations 310 CMR 19,132(1)h* including landfill contaminant indicator parameters, metals and volatile organic compounds (VOCs). Stations sampled included the fourteen new FCSA monitoring wells and fourteen existing monitoring wells.

5.2.1.1 Inorganic Data

Inorganic results in groundwater monitoring wells are summarized in Table 5-3 at the end of this section. Water quality data where drinking water quality guidelines or standards were exceeded are identified as follows:

pH: The pH levels for groundwater at various monitoring wells were outside of the SMCL range of 6.5 - 8.5 standard pH units. In general, groundwater in the surficial aquifer and confined aquifers was slightly acidic to acidic including the groundwater at upgradient well #1-08, while the pH of the bedrock aquifer was alkaline. High levels of alkaline groundwater (high pH) detected in the water sample from bedrock monitoring well #4-08 is probably due to cement grout infiltration of the sand pack during well construction and is not likely representative of natural conditions in the bedrock aquifer.

Total Dissolved Solids (TDS): Levels of TDS exceeded the SMCL of 500 mg/L in the groundwater at monitoring wells #2-08 and #4-08.

No other inorganic parameters detected in site groundwater exceeded MMCLs, ORSGs, or SMCLs in the seven monitoring wells sampled. Other parameters helpful in the evaluation of landfill impacts to groundwater quality but without specific guidelines or standards include:

Specific Conductance: Specific conductance levels were highly elevated (>1,000 umhos/cm) in the groundwater at wells #2-08 (1312 umhos/cm) and #4-08 (3317 umhos/cm), and elevated (>500 umhos/cm) at wells #3-68 (536 umhos/cm) and #8-08 (686 umhos/cm). Specific conductance at well #6-08 (confined aquifer at Gull Pond) was 464 umhos/cm.

Dissolved Oxygen: Dissolved oxygen levels less than 3.0 mg/L were detected in the groundwater at wells PGW-6, #6-68, #3-68, #3-80, #1-08 (upgradient well), #2-08, #5-08, #6-08, #7-08, #9-08, #10-08, #12-08, #1-83, #2-83, #3-83 and #4-83. Since low dissolved oxygen level was detected upgradient of the site in the groundwater, dissolved oxygen levels may not be a reliable indicator of landfill water quality impact for this site.

5.2.1.2 Metals Data

Metals results in groundwater monitoring wells are summarized in Table 5-4 at the end of this section. Metals water quality data for FCSA monitoring where drinking water quality guidelines or standards were exceeded are identified as follows:

Arsenic (As): Detected in the groundwater at levels exceeding the MMCL of 0.010 mg/L at wells #2-08 (0.026 mg/L) and #10-08 (0.020 mg/L). Well #2-08 is screened in the surficial aquifer directly downgradient of the landfill site. Well #10-08 is screened in the confined aquifer downgradient of the site at the KC Trail wetland off of Old Farm Road.

Arsenic (As) was also detected at trace concentrations (<0.0010 mg/L) in the groundwater at wells #6-89, #3-68, #4-08, #7-08, #8-08, #9-08 and #12-08, and at levels less than 0.0025 mg/L in the groundwater at wells #11-08 (0.0018 mg/L) and #1-38 (0.0024 mg/L).

Lead (Pb): Detected in the groundwater at upgradient well #1-08 (surficial aquifer) at a concentration of 0.018 mg/L exceeding the MMCL of 0.015 mg/L.

Lead (Pb ... was also detected at trace concentrations (<0.0010 at wells ... 2-08, #4-08 and #8-08, and at a concentration of 0

Iron (F ...): The metal iron (Fe) was detected in the gr dow ngra ... ient of the site at concentrations exceeding the back gro ... nd level of dissolved iron (Fe) in the surficial aquif well #1 ... 08 was 0.480 mg/L. Dissolved iron (Fe) levels were well #2 ... 08. Iron (Fe) concentrations are identified as follows

...urficial Aquifer: Iron (Fe) concentrations exceede ...pgradient well #1-08 (0.480 mg/L) and downgra ...g/L), #6-89 (3.70 mg/L), #2-08 (69.0 mg/L), # ...1.30 mg/L), and cross gradient wells #12-08 (3.60 ...nd #3-85 (0.570 mg/L).

...onfined Aquifer: Iron (Fe) concentrations exceed ...well #3-68 (2.40 mg/L), #9-08 (13.0 mg/L), #10-08 ...mg/L), #3-83 (0.460 mg/L) and #4-83 (2.30 mg/L).

Bedrock Aquifer: Iron (Fe) levels were less tha groundwater samples collected from bedrock monito

Man ... anese (Mn): The metal manganese (Mn) was d upgr ... dient and downgradient of the site at concentrations mg/L ... The background level of dissolved manganese upgr ... dient of the site at well #1-08 was 0.200 mg/L. Diss were ... measured up to 3.60 mg/L at well #6-89. Mangan iden ... fied as follows:

Surficial Aquifer: Manganese (Mn) concentrations mg/L at upgradient well #1-08 (0.200 mg/L) an (1.40 mg/L), #6-89 (3.60 mg/L), #2-08 (2.00 mg/ (.170 mg/L), #8-08 (3.50 mg/L), #11-08 (0.230 12-08 (0.150 mg/L), #1-03 (0.730 mg/L) and #3

...onfined Aquifer: Manganese (Mn) concentration ...g/L at well #3-68 (2.40 mg/L), #6-08 (3.10 mg/ ... (2.10 mg/L), #1-83 (0.250 mg/L), #2-83 (0. ...g/L).

...edrock Aquifer: Manganese (Mn) levels exceed ...e groundwater at well #5-08 (0.110 mg/L) but ...edrock monitoring well #4-08.

Sod... (Na): Sodium (Na) levels exceeded the SMCL upg...nt and downgradient of the site. The backgrou su... aquifer upgradient of the site at well #1-08 was we... easured up to 180 mg/L at bedrock well #4-08. ide... as follows:

...urficial Aquifer: Sodium (Na) levels excee ...pgradient well #1-08 (49 mg/L) and downgradi

08 (63 mg/L), #8-08 (87 mg/L) and #11-08 (25 mg/L), and cross gradient well #2-03 (45 mg/L).

Confined Aquifer: Sodium (Na) levels exceeded the SMCL of 20 mg/L in the groundwater of the confined aquifer at wells #3-80 (30 mg/L), #6-08 (39 mg/L) and #1-83 (61 mg/L).

Bedrock Aquifer: Sodium (Na) levels exceeded the SMCL of 20 mg/L at well #4-08 (180 mg/L) but were less than 20 mg/L at landfill well #5-08.

No other metals exceeded MMCL or SMCL guidelines for the "dissolved" metals in the FCSA groundwater analyses.

5.2.1.3 VOC Data

VOC results in groundwater monitoring wells are summarized in Table 5-5 at the end of this section.

No VOCs were detected in the groundwater at concentrations that exceed MMCL or ORSG standards or guidelines for drinking water.

VOCs detected in the groundwater samples are identified as follows:

Acetone: Detected in the groundwater at bedrock well #4-08 at an estimated concentration of 28 ug/L, less than the ORSG of 6,300 ug/L.

Chlorobenzene: Detected in the groundwater of the confined aquifer at well #3-68 at a concentration of 1.1 ug/L, less than the MMCL of 100 ug/L. Also detected in the confined aquifer at well #6-08 at a concentration of 3.4 ug/L and at well #10-08 at an estimated concentration of 0.87 ug/L.

cis-1,2-Dichloroethene: Detected in the groundwater of the confined aquifer at well #3-80 at a concentration of 2.6 ug/L, less than the MMCL of 70 ug/L.

Chloromethane: Detected in the confined aquifer groundwater at well #3-68 at an estimated concentration of 0.34 ug/L and well #3-80 at 0.46 ug/L, and in the surficial aquifer at well #8-08 at 0.32 ug/L. Also detected in the groundwater at bedrock well #4-08 at an estimated concentration of 0.53 ug/L and bedrock well #5-08 at an estimated concentration of 0.38 ug/L. There is no MMCL or ORSG for this compound.

Note that chloromethane was also detected in the laboratory quality control blank for well #5-08; the detection of this compound may not be representative of field conditions.

1,3-Dichlorobenzene: Detected in the surficial aquifer groundwater at the landfill site at well #2-08 at an estimated concentration of 4.2 ug/L. There is no MMCL or ORSG for this compound.

1,4-Dichlorobenzene: Detected in the surficial aquifer groundwater at the landfill site at well #2-08 at an estimated concentration of 4.3 ug/L, less than the MMCL of 5 ug/L.

Toluene: Detected in the groundwater at well #6-89 at a concentration of 11 ug/L, less than the MMCL of 1,000 ug/L.

Vinyl Chloride: Detected in the groundwater of the confined aquifer at well #3-80 at an estimated concentration of 0.47 ug/L, less than the MMCL of 2 ug/L. Also detected in the surficial aquifer at well #11-08 at a concentration of 1.9 ug/L.

1,4-Dioxane: Detected in the groundwater of the confined aquifer at well #3-80 at an estimated concentration of 0.21 ug/L, less than the ORSG of 3 ug/L. Also reported in the confined aquifer at well #6-08 at an estimated concentration of 0.24 ug/L.

Non-Target VOCs: Trace concentrations of non-target compounds were detected in groundwater samples from wells #3-68, #3-80, #1-83, #3-83, #2-08, #5-08, #6-08, #9-08 and #10-08. Non-target VOCs are identified as follows:

> **Chlorofluoromethane:** Reported in the groundwater sample from well #6-08 (3.0 ug/L).
>
> **Dichlorodifluoromethane:** Reported in the groundwater sample from wells #3-80 (0.66 ug/L) and #9-08 (0.27 ug/L).
>
> **Ethanethiol:** Reported in the groundwater sample from wells #1-83 (4.2 ug/L) and #3-83 (4.0 ug/L).
>
> **Ethyl Ether:** Reported in the groundwater sample from wells #3-68 (1.6 ug/L), #3-80 (3.3 ug/L), #2-08 (8.3 ug/L), #6-08 (2.8 ug/L) and #10-08 (1.2 ug/L).
>
> **Propanethiol:** Reported in the groundwater sample from well #1-83 (2.1 ug/L).
>
> **Propene:** Reported in the groundwater sample from well #5-08 (2.8 ug/L).

No other VOCs were detected above laboratory reporting limits.

5.2.2 FCSA Surface Water

One round of analysis of surface water for the parameters outlined under *Massachusetts Solid Waste Regulations 310 CMR 19,132(1)h* including landfill contaminant indicator parameters, metals and volatile organic compounds (VOCs). Stations sampled included the eight previous surface water stations (SW-1 thru SW-8) and nine additional surface water stations (SW-9 thru SW-17). Station SW-17 at the brickyard well field was substituted for a groundwater monitoring well that the MassDEP had required at this location. Additionally, three surface water samples at the SW-15 wetland to be obtained and analyzed for cyanide and dissolved lead (Pb), with follow-up samples analyzed for cyanide and physiologically available cyanide (PAC) at the SW-15A station.

5.2.2.1 Inorganic Data

Inorganic results in surface water stations are summarized in Table 5-3 at the end of this section. Water quality data where AWQC surface water quality criteria were exceeded are identified as follows:

pH: The pH levels for surface water at various monitoring stations were less than the Massachusetts Class B Fresh Water range of 6.5 - 8.3 standard pH units.

> **Gull pond:** The pH was less than 6.5 standard pH units at inlet station SW-1 (6.41 pH units) and downstream station SW-13 (6.49 pH units). However, pH

levels at Gull Pond station SW-2, inlet station SW-9 and downstream station SW-12 were within the AWQC range of 6.5-8.3 pH units.

KC Trail Seepage Area: The pH was less than 6.5 standard pH units at station SW-6 (6.28 pH units).

Brickyard Wellfield Springs: The pH was less than 6.5 standard pH units at station SW-8 (6.41 pH units) and station SW-17 (6.38 pH units).

Unnamed Pond 600 feet west of Gull Pond: The pH was less than 6.5 standard pH units at station SW-11 (6.38 pH units).

Dissolved Oxygen: Dissolved oxygen levels less than the Massachusetts Class B Fresh Water criteria of 5.0 mg/L at the following surface water stations:

Gull pond: The dissolved oxygen level was less than 5.0 mg/L at the inlet station SW-1 (3.15 mg/L). However, dissolved oxygen levels at the SW-9 inlet station, Gull Pond SW-2, and downstream stations SW-12 and SW-13 were above 5.0 mg/L.

KC Trail Seepage Area: Dissolved oxygen levels in the wetland were less than 5.0 mg/L at both stations SW-6 (4.60 mg/L) and SW-14 (3.23 mg/L).

Brickyard Wellfield Springs: Dissolved oxygen levels in the wetland were less than 5.0 mg/L at station SW-8 (4.84 mg/L) and station SW-17 (3.33 mg/L).

Wetland Area SW-15: 1,200 feet west of Old Amherst Landfill: The dissolved oxygen level was less than 5.0 mg/L at station SW-15 (0.75 mg/L) in the wetland.

Cyanide: Cyanide levels in surface water exceeded the AWQC guidelines for fresh water at the following surface water stations:

KC Trail Seepage Area: The cyanide level at station SW-6 of 0.0070 mg/L exceeded the AWQC Chronic Criteria guideline of 0.0052 mg/L.

Wetland Area SW-15: 1,200 feet west of Old Amherst Landfill: The cyanide level at station SW-15 (0.031 mg/L) in May 2005 exceeded the AWQC Acute Criteria guideline of 0.022 mg/L. The cyanide level at station SW-15A (0.035 mg/L) sampled in October 2008 exceeded the AWQC Acute Criteria guideline of 0.022 mg/L.

Follow-up sampling and analysis for cyanide and physiologically available cyanide (PAC) at the SW-15A station did not detect either cyanide or PAC at a detection level of 0.0060 mg/L.

No other inorganic parameters exceeded AWQC levels in the surface water. Other parameters helpful in the evaluation of landfill impacts to water quality but without specific guidelines or standards include:

Specific Conductance: Specific conductance levels were moderately elevated (200-500 umhos/cm) at some of the surface water stations.

Pomeroy Pond: Specific conductance level was 252.8 umhos at the SW-3 station. Pomeroy pond is located adjacent to the landfill.

Gull Pond: Specific conductance levels varied from 150.5 umhos/cm at the SW-1 inlet to levels between 300 to 400 umhos/cm at the SW-9 inlet station, SW-2 Gull Pond station and downstream stations SW-12 and SW-13.

KC Trail Seepage Area: Specific conductance levels in the wetland varied from 293.3 umhos/cm at SW-6 to 408.4 umhos/cm at SW-14.

Kettle Pond: Specific conductance level was 238.1 umhos/cm at the SW-7 station.

Brickyard Wellfield Springs: Specific conductance levels in the wetland varied from 312.9 to 357.9 umhos/cm at stations SW-17 and SW-8, respectively.

Hop Brook: Specific conductance levels in Hop Brook varied from 105.8 umhos/cm upstream of the landfill to 127.1 umhos/cm downstream of the site.

Owens Pond: Specific conductance level at the outlet of Owens Pond was 93.8 umhos/cm at the SW-10 station.

Unnamed Pond 600 feet west of Gull Pond: Specific conductance level was 398.1 umhos/cm at the SW-11 station.

Wetland Area SW-15: 1,200 feet west of Old Amherst Landfill: The specific conductance level was 355.5 umhos/cm at the SW-15 station in the wetland.

Alkalinity: Levels of alkalinity were less than 100 mg/L except at the following stations.

KC Trail Seepage Area: Alkalinity was 120 mg/L at the SW-14 station and 76 mg/L at the SW-6 station.

Kettle Pond: Specific conductance level was 238.1 umhos/cm at the SW-7 station.

Brickyard Wellfield Springs: Alkalinity was 120 mg/L at the SW-8 and SW-17 surface water monitoring stations.

Chemical Oxygen Demand (COD): COD levels were less than 100 mg/L except as follows.

KC Trail Seepage Area: COD levels were 360 mg/L at SW-8 and 120 mg/L at SW-14.

Unnamed Pond 600 feet west of Gull Pond: The COD level was 100 mg/L at the SW-10 station.

Wetland Area SW-15: 1,200 feet west of Old Amherst Landfill: The COD level was 1,400 mg/L at the SW-15 station in the wetland.

Total Dissolved Solids (TDS): TDS levels were moderately elevated (200-500 mg/L) at some of the surface water stations.

Pomeroy Pond: TDS level was 130 mg/L at the SW-3 station.

Gull Pond: TDS levels varied from 130 mg/L at the SW-1 inlet station to levels between 200 -300 mg/L at the SW-9 inlet station, SW-2 Gull Pond station and downstream stations SW-12 and SW-13.

KC Trail Seepage Area: TDS levels in the wetland varied from 170 mg/L at SW-6 to 200 mg/L at SW-14.

Kettle Pond: TDS level was 140 mg/L at the SW-7 station.

Brickyard Wellfield Springs: TDS levels in the wetland varied from 220-230 mg/L at stations SW-8 and SW-17, respectively.

Hop Brook: TDS levels in Hop Brook varied from 59 mg/L upstream of the site at station SW-4 to 88 mg/L at the downstream station SW-5.

Owens Pond: The TDS level was 130 mg/L at the SW-10 station.

Unnamed Pond 600 feet west of Gull Pond: The TDS level was 69 mg/L at the SW-11 station.

Wetland Area SW-15: 1,200 feet west of Old Amherst Landfill: The TDS level was 250 mg/L at the SW-15 station in the wetland.

5.2.2.2 Metals Data

Metals results from the surface water monitoring are summarized in Table 5-4 at the end of this section. Metals water quality data for FCSA monitoring where AWQC guidelines were exceeded are identified as follows:

Iron (Fe): Concentrations of dissolved iron (Fe) in the surface water exceeded the AWQC Chronic Criteria of 1.0 mg/L at the following stations.

Gull Pond: The iron (Fe) level at the SW-1 inlet station of 1.60 mg/L exceeded the AWQC Chronic Criteria of 1.0 mg/L. Iron (Fe) levels varied from 0.030 mg/L at the SW-9 inlet station to 0.250 mg/L at the SW-13 downstream station.

KC Trail Seepage Area: The iron (Fe) level at the SW-14 station of 6.40 mg/L exceeded the AWQC Chronic Criteria of 1.0 mg/L. The iron (Fe) level at the SW-6 station was 0.096 mg/L.

Wetland Area SW-15: 1,200 feet west of Old Amherst Landfill: The iron (Fe) level was 5.20 mg/L at the SW-15 station, exceeding the AWQC Chronic Criteria of 1.0 mg/L.

Lead (Pb): Concentrations of dissolved lead (Pb) in the surface water exceeded the AWQC Chronic Criteria of 0.0032 mg/L at the following stations.

Wetland Area SW-15: 1,200 feet west of Old Amherst Landfill: The lead (Pb) levels varied from 0.0074 mg/L at SW-15B to 0.0140 mg/L at SW-15A, both exceeding the AWQC Chronic Criteria for lead (Pb) of 0.0032 mg/L. The lead (Pb) level was 0.0018 mg/L at SW-15, less than the AWQC Chronic Criteria level.

No other dissolved metals exceeded AWQC levels in the surface water for the FCSA monitoring. The other metal that is helpful in the evaluation of landfill impacts to water quality for this site is arsenic (As):

Arsenic (As): Trace (<0.0010 mg/L) to low (<0.010 mg/L) concentrations of arsenic (As) were detected in many of the surface water samples including upstream and downstream samples from Hop Brook. The AWQC Chronic Criteria for arsenic (As) in surface water is 0.850 mg/L.

Pomeroy Pond: Arsenic (As) detected at a trace concentration of 0.00053 mg/L.

Gull Pond: Arsenic (As) concentrations were 0.0010 mg/L or less Gull Pond and Gull Pond drainage samples.

KC Trail Seepage Area: Arsenic (As) concentrations in the wetland varied from 0.0018 mg/L at SW-6 to 0.00042 mg/L at SW-14.

Kettle Pond: Arsenic (As) detected at trace level of 0.00055 mg/L.

Brickyard Wellfield Springs: Arsenic (As) was not detected.

Hop Brook: Trace levels of arsenic (As) were detected in the upstream and downstream Hop Brook samples are equivalent concentrations of 0.00051 mg/L upstream at SW-4 and 0.00043 mg/L downstream at station SW-5.

Owens Pond: Arsenic (As) was not detected.

Unnamed Pond 600 feet west of Gull Pond: Arsenic (As) detected at a trace concentration of 0.00063 mg/L.

Wetland Area SW-15: 1,200 feet west of Old Amherst Landfill: Arsenic (As) was detected at a concentration of 0.0028 mg/L.

5.2.2.3 VOC Data

VOC results from surface water monitoring are summarized in Table 5-5 at the end of this section.

No target VOCs were detected in the surface water samples.

Non-Target VOCs: Trace concentrations of non-target VOCs were identified in two of the sixteen FCSA surface water samples are:

Carbon disulfide: Reported at trace (<10 ug/L) levels in the SW-7 sample at an estimated concentration of 2.7 ug/L. Station SW-7 is located at the Kettle Pond that is about 300 feet north of Gull Pond.

Ethyl Ether: Reported at trace (<10 ug/L) levels in the SW-8 sample at an estimated concentration of 1.2 ug/L. Station SW-8 is a spring located at the former Brickyard Wellfield.

5.2.3 FCSA Sediment

One round of sampling and analysis of sediment for the parameters outlined under *Massachusetts Solid Waste Regulations 310 CMR 19,132(1)h* including RCRA 8 metals and volatile organic compounds (VOCs) at stations SED-1, SED-4, SED-5, SED-6, SED-7, SED-8, SED-14, SED-15 and SED-16. Additional sediment sampling and analysis required by the MassDEP during the FCSA is as follows: Stations are:

Station SED-1: Four samples for arsenic (As) with one sample in the approximate SED-1 location, then one west, one east and one south.

KC Trail Area (Stations SED-6, SED-14 and SED-16): Twelve additional samples for arsenic (As) and cadmium (Cd) located along edges of the visibly-impacted wetland area and within the wetland to delineate metal concentrations. (Ten samples were requested via email request with another two samples requested in the field during review of sampling stations.)

Station SED-15: Three samples for mercury (Hg) analysis. One sample in the approximate SED-15 location and two nearby samples collected at the edges of the wetland area.

Sediment sampling stations are shown on the FCSA Site Plan provided in Appendix B. The data is compared to MassDEP Sediment Screening Criteria where possible for metals. VOC data is compared to MassDEP MCP Method 1 Clean-up Standards for soils since there are no MassDEP VOC standards for sediments. Analytical data is summarized as follows at sampling stations:

Gull Pond Station SED-1: Arsenic (As) was detected in four samples at levels ranging from 64 mg/kg to 130 mg/kg exceeding the MassDEP Sediment Screening Criteria of 33 mg/kg. No other metals were detected at concentrations exceeding MassDEP Sediment Screening Criteria. Elevated levels of iron (Fe) were detected at concentrations exceeding Ontario Guidelines for Aquatic Sediment (1993).

VOC analysis detected acetone and 2-butanone at concentrations of 240 ug/kg and 120 ug/kg, respectively. VOC concentrations were less than MassDEP MCP Method 1 Clean-up Standards (for soils).

KC Trail Seepage Area Stations SED-6, SED-14 and SED-16: Cyanide was detected at a concentration of 3.7 mg/kg in the SED-6 sediment sample. There is no standard or guideline for cyanide in sediment.

Metals analysis detected arsenic (As) and cadmium (Cd) at levels exceeding MassDEP Sediment Screening Criteria of 33 mg/kg and 5.0 mg/kg, respectively, at the SED-6, SED-6K, SED-14 and SED-16 sample stations. Arsenic (As) concentrations varied from 53 mg/kg (SED-6) to 260 mg/kg (SED-6K) at these stations while cadmium (Cd) levels varied from 5.9 mg/kg (SED-16) to 11 mg/kg (SED-6K). The highest concentrations of arsenic (As) and cadmium (Cd) were in the middle of the wetland area at the SED-6K location. Elevated levels of iron (Fe) were detected at concentrations exceeding Ontario Guidelines for Aquatic Sediment (1993).

VOC analysis detected 2-butanone at an estimated concentration of 110 ug/kg that is less than MassDEP MCP Method 1 Clean-up Standards (for soils).

Kettle Pond Station SED-7: No metals were detected at concentrations exceeding MassDEP Sediment Screening Criteria during the FCSA monitoring round. Mercury (Hg) had previously been detected at a concentration of 0.18 mg/kg that is equal to the MassDEP Sediment Screening Criteria guideline of 0.18 mg/kg.

No VOCs were detected during the FCSA monitoring round. Trace levels of toluene and two non-target compounds were previously detected in the sediment at station SED-7. The toluene concentration of 5.7 ug/kg was well below the MassDEP MCP Method 1 Clean-up Standard for soils of 90,000 ug/kg.

Brickyard Wellfield Station SED-8: No metals were detected at concentrations exceeding MassDEP Sediment Screening Criteria during the FCSA monitoring round. Copper (Cu) was previously detected at a concentration of 370 mg/kg that exceeds the MassDEP Sediment Screening Criteria guideline of 150 mg/kg.

No VOCs were detected during the FCSA monitoring round. A trace level of chlorobenzene was previously detected in the sediment at station SED-8 at a concentration of 3.0 ug/kg that is well below the MassDEP MCP Method 1 Clean-up Standard for soils of 8,000 ug/kg.

Hop Brook Stations SED-4 (Upstream) and SED-5 (Downstream): No metals were detected at concentrations that exceed MassDEP Sediment Screening Criteria during either the Interim CSA or FCSA monitoring rounds. Moderately elevated levels of iron (Fe) were detected at both stations at concentrations exceeding lowest effect level (LEL) of the Ontario Guidelines for Aquatic Sediment (1993).

No VOCs were detected during the FCSA monitoring round at either the upstream (SED-4) or downstream (SED-5) stations on Hop Brook. A trace level of toluene was detected during the November 2005 monitoring round at the upstream SED-4 station but at a concentration of 3.5 ug/kg that is well below the MassDEP MCP Method 1 Clean-up Standard for soils of 90,000 ug/kg.

SW-15 Wetland Area Station SED-15: Mercury (Hg) was detected at concentrations raging from 0.19 mg/kg (SED-15) to 0.50 mg/kg (SED-15B) at three sampling stations, exceeding the MassDEP Sediment Screening Criteria guideline of 0.18 mg/kg. No other metals were detected at concentrations exceeding MassDEP Sediment Screening Criteria.

VOC analysis detected the compound 2-butanone at an estimated concentration of 39 ug/kg that is less than MassDEP MCP Method 1 Clean-up Standards for soils of 8,000 ug/kg.

5.2.4 FCSA Soil Gas - Landfill Site

The FCSA landfill environmental monitoring program included one round of soil gas monitoring of existing and new gas monitoring wells and existing soil gas points for percent methane, percent oxygen and hydrogen sulfide gas in parts per million (ppm). MassDEP required that soil gas monitoring data be reported in conformance with *MassDEP Solid Waste Regulations 310 CMR 19.132(4)* including requirements for 2-hour and 24-hour notifications.

No exceedance of landfill gases in soil air were detected during the FCSA monitoring round.

5.3 Identification of "Contaminants of Concern (COCs)"

5.3.1 Interim CSA Contaminants of Concern (COCs)

Environmental monitoring for the Interim CSA study was conducted in November 2005. The program included collection and analysis of 13 groundwater samples, and 9 surface water samples and 9 sediment samples. Analytical parameters included the general water chemistry, metals and VOC analyses required under *Massachusetts Solid Waste Regulation 310 CMR 19.132(1)h* with the addition of pesticide analyses for the groundwater samples. Total metals were analyzed at all sampling stations. Potential "Contaminants of Concern or COCs" were identified by comparison to applicable standards as summarized below:

5.3.1.1 Groundwater

Groundwater COCs included an acidic to alkaline pH outside of the range of 6.5-8.5 standard pH units, and the metals barium (Ba), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), manganese (Mn), mercury (Hg) and zinc (Zn). Metals analysis was by "total" metals (not dissolved) in the groundwater. No volatile organic compounds (VOCs) were identified as COCs in groundwater.

Other potential landfill groundwater quality impacts include slightly to moderately elevated levels of alkalinity, chemical oxygen demand (COD), chloride, sulfate and TDS, and trace concentrations of VOCs at levels less than 10 ug/L (<10 ppb).

5.3.1.2 Surface Water

Surface water COCs included a dissolved oxygen content of less than 5 mg/L, and the metal lead (Pb). No VOCs were identified as COCs in the surface water.

Other potential landfill surface water quality impacts are moderately elevated to elevated levels of barium (Ba), iron (Fe) and manganese (Mn), and trace concentrations of VOCs at levels less than 10 ug/L (<10 ppb).

5.3.1.3 Sediment

Sediment COCs include the metals arsenic (As), copper (Cu), iron (Fe), lead (Pb), manganese (Mn), mercury (Hg) and zinc (Zn). No VOCs were identified as COCs in the sediment samples.

Other potential landfill sediment quality impacts are moderately elevated to elevated levels of alkalinity, COD and chloride, and moderately elevated levels of the metal barium (Ba).

5.3.2 FCSA Contaminants of Concern (COCs)

The FCSA analytical data indicates that the following analytes are contaminants of concern for the Old Amherst Landfill site:

5.3.2.1 Groundwater

Groundwater contaminants of concern (COCs) identified in the FCSA analytical data are:

- Arsenic (As) at trace to low concentrations with two groundwater samples exceeding the MMCL of 0.010 mg/L.

- Iron (Fe) at elevated concentrations exceeding the SMCL of 0.3 mg/L in many of the groundwater samples; the concentration of iron (Fe) was higher in downgradient groundwater samples versus the upgradient background sample at well #1-08.

- Manganese (Mn) at elevated concentrations exceeding the SMCL of 0.05 mg/L in many of the groundwater samples; the concentration of manganese (Mn) was higher in downgradient groundwater samples versus the upgradient background sample at well #1-08.

Sodium (Na) is not identified as a COC since sodium (Na) is also present in elevated concentrations upgradient of the landfill in the groundwater.

Other metals such as barium (Ba), cadmium (Cd), chromium (Cr), lead (Pb), mercury (Hg) and zinc (Zn) were either detected at low frequencies and low concentrations, also detected in the groundwater upgradient of the site, or were detected during total metals analysis and not during dissolved metals analysis and are therefore not considered COCs.

No VOCs are identified as COCs in the groundwater. The few VOCs reported in groundwater samples were detected at trace (<10 ug/L) to low (<50 ug/L) concentrations at low frequencies in the groundwater samples.

5.3.2.2 Surface Water

Surface water COCs include:

- Lead (Pb) at the SW-15 wetland area; detected in three of four samples at concentrations exceeding AWQC criteria and the MMCL for drinking water.

Other contaminants such as cyanide which was were detected in one of three samples at the KC Trail wetland area and two of five samples at the SW-15 wetland area was detected low concentrations and low frequencies and therefore was not identified as a COC for surface water at these locations.

No VOCs are identified as COCs in the surface water. The two non-target compounds reported in surface water samples were detected at low frequency and trace concentrations.

5.3.2.3 Sediment

Sediment COCs include:

- Arsenic (As) at the Gull Pond SW-1 station; detected in four of six samples at concentrations exceeding MassDEP Sediment Screening Criteria.

- Arsenic (As) and cadmium (Cd) at the KC Trail wetland area (stations SED-6, SED-14 and SED-16). Arsenic (As) was detected in five of sixteen samples at concentrations exceeding MassDEP Sediment Screening Criteria. Cadmium (Cd) was detected in four of sixteen samples at levels exceeding MassDEP Sediment Screening Criteria.

- Mercury (Hg) at the SW-15 wetland area; detected in four of four samples at concentrations exceeding MassDEP Sediment Screening Criteria for mercury (Hg).

No VOCs are identified as COCs in sediment. VOCs reported in sediment samples were detected at low frequencies and low concentrations.

5.3.2.4 Soil Gas - Landfill Site

Although methane was not detected at concentrations exceeding applicable US EPA and MassDEP threshold concentrations during FCSA soil gas monitoring along the perimeter of the landfill site, methane is a combustible gas generated in the landfill by the anaerobic decomposition of municipal solid waste and is released to the environment through either venting to the atmosphere or by subsurface migration in the soil air at the edges of the landfill. Therefore, methane is a COC for the site in the soil gas at facility boundaries where it has the potential to impact off-site structures and subsurface utilities.

5.4 Summary of CSA Monitoring Program Findings

The CSA environmental monitoring program involved the monitoring of groundwater surface water, sediments and soil gas. A summary of the findings is presented below:

5.4.1 Indicator Parameters

5.4.1.1 Groundwater

Potential groundwater quality impacts include moderate elevated (>500 umhos/cm) to elevated (>1,000 umhos/cm) specific conductance, elevated levels (>500 mg/L) of total dissolved solids (TDS) and low <3.0 mg/L) levels of dissolved oxygen.

5.4.1.2 Surface Water

Potential surface water quality impacts include moderate elevated (200-500 umhos/cm) specific conductance, alkalinity (100-300 mg/L), chemical oxygen demand (COD) above 100 mg/L, moderated elevated TOS (200-500 mg/L), pH less than 6.5 standard units, trace levels of cyanide and low <3.0 mg/L) levels of dissolved oxygen.

5.4.1.3 Sediments

Cyanide was identified in one of two samples at the KC Trail wetland at a level of 3.7 mg/kg.

5.4.2 Metals

5.4.2.1 Groundwater

Potential groundwater quality impacts include low levels of the metals arsenic (As), and elevated levels of the metals iron (Fe) and Manganese (Mn) in the groundwater. These metals are identified as COCs for the site.

Sodium (Na) levels exceeded the SMCL of 20 mg/L both upgradient and downgradient of the landfill ion the groundwater.

5.4.2.2 Surface Water

Potential surface water quality impacts include trace levels of arsenic (As) and trace to low levels of lead (Pb), and elevated levels of iron (Fe) and manganese (Mn) in the surface water.

5.4.2.3 Sediments

Potential landfill sediment quality impacts include the metals arsenic (As), cadmium (Cd), mercury (Hg) and elevated levels of iron (Fe). The elevated metals concentrations in the sediments are the likely result of groundwater discharge to downgradient wetland areas.

5.4.3 Volatile Organic Compounds (VOCs)

5.4.3.1 Groundwater

Few VOCs were detected at generally trace to low concentrations in the groundwater. However, individual compounds were infrequently detected in various groundwater samples. None were found to be wide ranging in the surficial, confined or bedrock aquifers or frequently detected at high concentrations.

5.4.3.2 Surface Water

Very few target VOCs and non-target compounds were detected in the surface water samples at trace concentrations. None of the VOCs were found to be frequently detected in the surface water samples.

5.4.3.3 Sediments

Very few target VOCs and non-target compounds were detected in the sediment samples at trace to low concentrations. Identified compounds include acetone, 2-butanone, chlorobenzene, 1,4-dichlorobenzene and toluene, and the non-target compounds dimethyl ether, hexanal and pentanal.

5.4.4 Soil Air - Landfill Gases

Landfill gases including methane, carbon dioxide and trace levels of hydrogen sulfide gas are identified as potential landfill impacts to soil air on-site and adjacent to the site. These gases are generated in the landfill and migrate in the subsurface off-site through unsaturated soils and may potentially impact abutting properties. Low oxygen level is also identified as a potential landfill gas impact to soil air.